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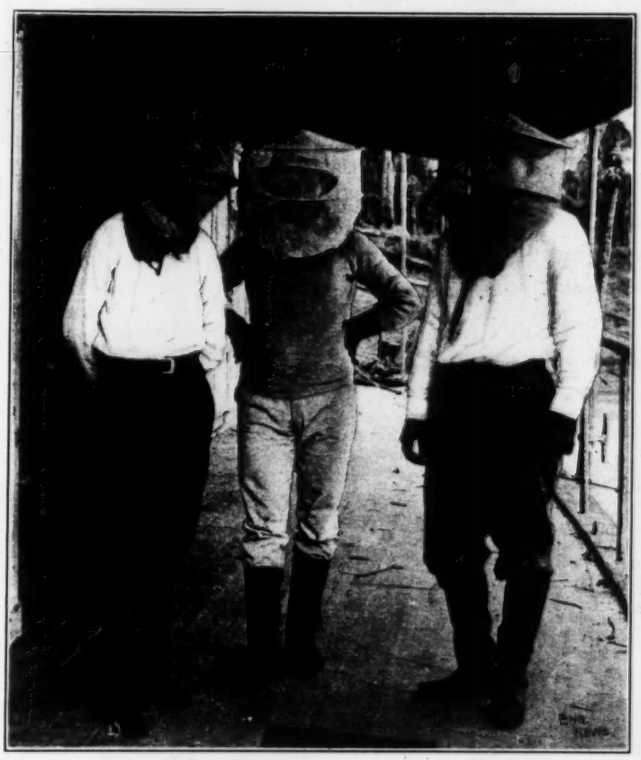
Mosquito-Proof Headgear on the Madeira-Mamore Railway Survey.

When the mosquito was regarded only as a peculiarly active insect with a sharp proboscis, his stings were suffered with more or less patience, or attempt was made to ward them off by the application of some sort of ointment or "dope." But since his character as a disease bringer has been so firmly established, more effective means of discouraging his attentions have been resorted to. The accompanying half-tone, originally published in the "Bulletin of the International Bureau of American Republics," shows the extent of these precautions by the engineers now engaged in building the Madeira-Mamore Ry., in the jungles of South America, where the disease-bearing mosquito is especially persistent. It will be noted that not only is the head protected by a net, but that the hands and feet also, are covered tightly, so that there is no exposed part of the body.



ENGINEERS ON THE MADEIRA-MAMORE RY. PROTECTED AGAINST MOSQUITOS.

Fire Protection in San Francisco Under the New Building Law.

The following summary of the fireproofing and fire-protection provisions of a new building ordinance of San Francisco, Cal., may prove interesting to many.

FIRE LIMITS AND FIREPROOF ROOF LIMITS.—The ordinance establishes (1) fire limits, embracing the northeasterly or roughly the business part of the city, and (2) a larger area (including this) within which shingle roofs are not permitted.

BUILDINGS WITHIN FIRE LIMITS.—Three classes of buildings are permitted within the fire limits:

Sec. 74. Class A buildings are defined as those having fireproofed frames of steel and with all structural parts of incombustible material. Walls shall be of brick, stone, concrete or reinforced concrete. Class A buildings with all wall loads above the third floor carried on the steel frame shall not be limited as to height. Class A buildings for self-supporting curtain or bearing walls on the exterior shall be limited in height to 86 ft. Class A buildings may be built anywhere in the city.

Sec. 75. Class B buildings are defined as those having a frame of reinforced concrete carrying all wall and floor loads. All structural parts shall be of incombustible material. Walls shall be of brick, stone or reinforced concrete. The maximum limit of height of Class B buildings shall be 102 ft., and they may be built anywhere in the city.

Sec. 76. Class C buildings are defined as those having exterior walls of brick, stone or concrete and an interior frame of combustible material. The walls may be bearing or curtain walls and the interior supports may be timber joists, timber or steel girders, and timber, steel or cast-iron columns, or timber studding. Class C buildings built with the interior of mill construction, or with all joists, girders, studding, furring and soffits of stairs lathed with metal lath and plastered may be built to a height not to exceed 84 ft. Class C buildings with all joists, girders, studding, furring and soffit of stairs lathed with wooden lath and plastered, or not lathed and plastered, may be built to a height not to exceed 55 ft. Class C buildings may be built anywhere in the city.

Sec. 79. The heights of buildings shall not exceed the heights given under the different classes except that stair and elevator houses, water-tanks, towers and spires may exceed the limits. Towers and spires on Class C or frame buildings may extend 100 ft. above the roof, but no such tower or spire shall occupy more than one-quarter of the street frontage of the building, nor shall it have a base area exceeding 1,000 sq. ft. Such towers and spires shall not be used as a dwelling, place of manufacture nor storage room and shall be covered with fireproof materials.

It will be seen that "Class C" buildings may be of ordinary timber frame construction (they may have wooden roof trusses of any span), except that the outer walls must be of incombustible material and the roof must be fireproof. This latter requirement is defined more fully; it appears that the structural part of the roof in Class C buildings may be of wood, on wooden beams or trusses, but it must be covered as follows:

Sec. 235. Within the fireproof roofing limits the roofs of all classes of buildings hereafter erected shall be covered with either metal, slate, tile, terra-cotta, asbestos shingles, asbestos building lumber not less than one-eighth of an inch thick; a three-ply pure asbestos roofing * * * ; at least five layers of saturated roofing felt * * * ; provided that said saturated roofing felt or said two layers of prepared roofing shall be cemented together with asphaltum and then covered with a flowing coat of asphaltum in which shall be imbedded clean screened gravel of sufficient quantity to thoroughly cover the surface * * * ; and provided further that said saturated roofing felt or said two layers of prepared roofing when laid over wooden sheathing shall be laid over a surface of sheet asbestos weighing not less than 20 lbs. per 100 sq. ft.

The supports, rafters and all parts of roof within the fireproof roofing limits *rising at any point to a height of more than 20 ft. from the top of the masonry walls* shall be built of fireproof material.

The details specified for timber framing in Class C are substantially in accordance with good practice in frame-house construction. Steel or reinforced-concrete parts in Class C buildings must be in accordance with the requirements for similar parts in fully fireproof buildings. Also, if the exterior walls are curtain walls carried on steel or reinforced concrete framing, the interior ties of this framing and the interior columns supporting these ties must be of steel (fireproofed as in fully fireproof buildings) or of reinforced concrete.

THEATERS, HOSPITALS AND HALLS.—The general descriptions above quoted are amplified for the case of certain kinds of buildings serving special purposes. Thus, theaters must be of Class A construction, i. e., fully fireproofed, and the details of exits, passages, stairs, stage, etc., are carefully specified to give a fireproof result. Moving picture resorts seating less than 400 may be Class C. Schools, hospitals, public halls, etc., may be Class C if seating not over 1,000. Department stores and warehouses may be of Class C.

HOTELS AND LODGING HOUSES.—Tenement houses are covered by the State tenement-house law. All hotels and lodging houses may be of Class C, but if they are to house less than 100 people and are outside the fire limits, they may be of all wood construction. Such may not be higher than three stories, however.

WOODEN PORCHES.—Porches of wood are permitted in Class C buildings, up to the fourth story, and may carry enclosures to form rooms, as quoted below. This evidently may make part of the exterior of such buildings to be of wood even within the fire limits. Such porches, it ap-

pears, may be built even on hotels or lodging houses.

Sec. 234. Porches of wood may be attached to buildings of Class C, but not to buildings of Class A nor Class B, and shall be constructed without concealed spaces in any part, and without enclosures other than open rail or wire guard not over 4 ft. above floor, except as hereinafter specified. Said porches must not be placed higher than the fourth story of any building, nor project over the line of any street, lane, alley or place.

Enclosures on such porches shall not exceed 7 ft. from floor to ceiling, and shall not, for a hotel or lodging-house, exceed 50 superficial feet of floor room, or for any other building exceed 25 superficial feet of floor room, and shall be used only as water-closets or privies.

Roofs of both porches and enclosures, also the entire exterior of enclosures, shall be covered with tin in the manner specified in Sections 202 and 204 of this ordinance for covering fireproof shutters and doors; or with corrugated iron nailed to stud frame without boarding.

STAIRWAYS AND ELEVATOR SHAFTS.—Some of the provisions regarding stairway construction have a bearing on fire conditions. It appears that fireproof enclosures of stairways are required only in buildings over 12,500 sq. ft. ground area, and in Class C buildings the stairs may be of wood even when required to be thus enclosed. The requirements as to fireproofing elevator shafts are not ideal.

Sec. 240. Open elevators or elevators without fireproof enclosures may be used in buildings of Classes A and B. They may also be used in buildings of Class C, provided they are located and operated in well holes of fireproof staircases (oak treads may be used); provided, the staircases are entirely surrounded by walls, either of fireprooof material or of studding covered on both sides with metal lath and plaster.

Open elevators may be used in all buildings provided they do not pass the ceiling of the first story.

Buildings occupied or used entirely for manufacturing or mercantile purposes may have open elevators with hanging enclosures around the openings at each floor, extending downward at least 3 ft. and covered with metal on both sides from soffit of the hanging enclosures to the top of the floor above, and trap-doors covered with metal on the underside at each floor.

Elevators, hoists, dumb-waiters and lifts and all openings or shafts passing through the floor or floors in all buildings other than Classes A and B, and under all other conditions, shall be enclosed by walls of noncombustible material, or of studding covered on both sides with iron, or with metal lath and plastering not less than three-quarters of an inch in thickness.

Sec. 239. The bottom of every elevator and of every stairway leading to a basement shall be enclosed with a door and a tight partition extending from the basement floor to the under side of the first floor, which enclosure shall be of the construction required for a building of the class in which it is placed, and shall contain no glass except wire glass ¼-in. thick in metal sash.

WOODEN SHEDS.—Wooden sheds are permitted within the fire limits up to a size of 1,500 sq. ft. ground area and 15 ft. height.

Sec. 156. Sheds erected within the fire limits, if not constructed entirely of incombustible material, shall have a timber frame, without boarding, covered on the outside and roof with corrugated iron or sheet metal.

Sheds shall be erected on the ground, shall not exceed 15 ft. in height, shall be open on at least three sides and shall not cover an area exceeding 1,500 sq. ft.

No fence shall be used as any portion of such shed.

LIMITS OF FLOOR AREAS.—The size of unbroken floor area is not limited in Classes A and B. In Class C there are limits, as stated below, from which it will be seen that practically there is no limit even in this type (wood interior); also, an extension of area limit is permitted when automatic sprinklers are used, though this is not likely to play much of a part in actual practice.

Sec. 80. . . . In buildings of Class C, mill and frame construction wherever built no single floor area between exterior, division or party walls shall exceed 10,000 sq. ft., except that in buildings of Class C construction not exceeding one story in height, and used for warehouse purpose only, a single floor area between exterior division or party walls may be built with an area of 19,000 sq. ft.; provided, however, in case the foregoing described buildings are completely equipped with a system of automatic sprinklers in a manner approved by the Board of Fire Underwriters of the Pacific, the said area may be increased 50 per centum. . . .

Attics or the unfinished spaces between the ceiling and roof rafters of every Class C or frame building shall be divided into compartments or rooms in order to prevent the rapid progress of fire. Such compartments shall not have a floor area of more than 2,500 sq. ft.

SPRINKLERS, ETC.—Hose pipes are required in theaters on each floor and balcony in both auditorium and stage on each side, and in property room and carpenter shop. They are to be supplied from automatic fire pumps within the building. A standpipe with connection outside the building is also required, and various auxiliary fire equipment. Automatic sprinklers covering the entire stage space are required, with supply from a tank over the stage roof. Sprinklers are to be placed also in dressing-rooms, below stage, etc. Water casks and buckets are to be kept on the stage.

Cold-storage houses must have their hallways, passages and elevator shafts protected by automatic sprinklers. There are no other sprinkler requirements except for theaters.

Fire department standpipes are required on all buildings 4 stories or more in height.

Inside or wet standpipes connected with hose reels are required in all buildings over 58 ft. high.

FIRE DOORS AND SHUTTERS.—Automatic fire doors are required on all openings through exterior, division or party walls whereby communication is made with adjoining buildings or rooms, except in frame houses.

Window openings in exterior walls facing on a lot line, court or yard within 30 ft. of another building, and all wall openings in factory and store buildings over two stories high must have either fire shutters or wire-glass.

MISCELLANEOUS.—Fire-escapes are quite generally required.

Terra-cotta chimneys are permitted only if "a United States patent has been issued" for them, and all such smoke-pipes now in use not conforming to such patent must be removed. Terra-cotta lined brick chimneys, "patent chimneys," and in concrete walls also concrete chimneys, are the only chimneys permitted in buildings.

Dangerous articles may not be stored or sold in any part of a theater building. Explosive or inflammable compounds or combustible materials may not be stored under any stairway, or used in such a place or way as to interfere with egress in case of fire. These are the only limitations in the ordinance on the storage or use of dangerous inflammables.

ELECTRIC TRACTION ON BOSTON RAILROADS.—The joint board, made up by the Massachusetts Railroad, the Boston Transit, the Metropolitan Park and the Harbor and Land Commissions, has reported to the Legislature on commercial and transportation matters related to the improvement of the Boston metropolitan district as directed by the General Court in 1909. The report in part discusses the installation of electric traction in the railway terminals—a matter which has been brought before several commissions and the Legislature by the attempts of the Boston & Eastern Ry. to gain rights to build a high-speed electric line, as noted in Engineering News, 1908, July-Dec., pp. 196, 504, 644. The report states:

Most of the suggested improvements in the passenger and freight service of the metropolitan district are predicated upon the substitution of electricity for steam as a motive power. As the Metropolitan Improvements Commission reported that the question of transportation was the paramount question affecting the commercial and industrial development of the district and of the State, and as that opinion has been plainly endorsed by the Legislature and by the public, and is fully concurred in by the board, it becomes of primary importance that the work of studying the problem of electrification should be begun at once in a determined and comprehensive way.

After reviewing the work done by the New York Central and the New York, New Haven & Hartford roads in and about New York City, the board recommends that the Legislature require all railroads operating within the metropolitan district to study the "electrification" of both passenger and freight services and to report their findings to the board by Sept. 1, 1910.

Area of Contact Between Car Wheels and Rails.

By E. L. HANCOCK.*

The increase in wheel loads and the consequent destructive effect upon wheel and rail led the writer to undertake some experimental work to determine the area of contact between car wheels and rails. All tests made heretofore have been made with the rail resting on a solid foundation. This eliminates the bending of the rail and the bending of the ties. All laboratory tests have been made on single wheels or portions of wheels, eliminating the effect of the bending of the axle. Tests made by Dean W. F. M. Goss on wrought iron car axles (see "Digest of Physical Tests," Vol. II) show that the bending of the axle is an important factor in area of contact tests. His investigation showed that the center of the car axle might deflect ⅛-in. without exceeding the elastic limit of the material, and that this deflection may cause a change of gage of 0.3 in.

For the purpose of the tests a small section of track was built upon the base of a testing machine as described below. It was thought best to use wheels and rails that are in general service. These were supplied by the Lake Erie & Western

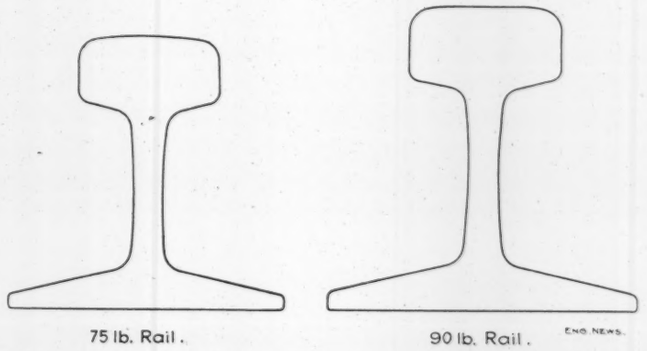


FIG. 1. SECTIONS OF RAILS USED IN CAR WHEEL CONTACT AREA TESTS.

Railroad and consisted of four pairs of wheels mounted upon their axles and portions of a 90-lb. rail and a 75-lb. rail. The rail sections are shown in Fig. 1. The dimensions of the wheels and axles are shown by Fig. 2 and Table I. The pair A was a pair of new cast-iron wheels designed to carry, according to M. C. B. specifications, probably 22,000 lbs. Weight of wheels and axle was 1,800 lbs. Pair B was a pair of cast iron wheels, slightly worn, designed to carry 15,000 lbs. and weighing with axle 1,500 lbs. Pair C was a pair of cast-iron wheels, considerably worn. The wheel C_a was worn hollow on the tread. The other wheel, C_b, was not quite so badly worn. These were designed to carry 15,000 lbs. and weighed with axle 1,430 lbs. Pair D was a pair of steel tired wheels, new, weighing with axle 2,675 lbs. and designed to carry, probably, 31,000 lbs.

The roadbed was built upon one side of the extension base of a 200,000-lb. Riehle testing machine in the Laboratory for Testing Materials of Purdue University. This machine with track and wheels is shown in section in Fig. 3 and by photograph in Fig. 4. In a suitably constructed box, about one foot of crushed stone was placed and upon this were laid two ties with rail sections spiked in place. The ties were placed 14 ins. center to center and the rail sections were 2 ft. long, placed at standard gage. The weight of this roadbed and wheels was counterbalanced by cast iron piled upon the other arm of the machine. This is shown in Fig 4. A box girder attached to the moving head of the machine and resting on a column at one end was the means of applying pressure to the journals through an auxiliary beam at the other end. The load was applied to the axles at the journals, approximating as nearly as possible the conditions of service

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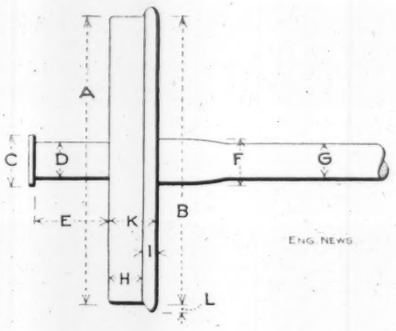


Fig. 2. Diagram for Dimensions of Car Wheels Used in Contact Area Tests.
(Letters indicate dimensions given in Table I.)

TABLE I.—DIMENSIONS OF CAR WHEELS TESTED FOR RAIL CONTACT AREA.

	Pair A	Pair B		Pair C		Pair D
	New wheels	Worn		Worn		Steel wheels
	same	E353946	135200	13137	11663	same
A*....	32 9/16	32 7/8	32 7/8	32 13/16	33	35 17/32
B	33	33 1/16	32 7/8	32 7/8	32 7/8	35 11/16
C	5 1/8	4 11/16	4 11/16	4 5/8	4 5/8	6 1/16
D	4 1/4	3 3/4	3 3/4	3 21/32	3 21/32	5
E	8 1/4	7 5/16	7 5/16	7 3/16	7 3/16	9
F	5 3/8	5 1/8	5 1/8	5	5	6 3/4
G	4 1/16	4 1/4	4 1/4	4 1/4	4 1/4	5 11/32
H	4	4 3/16	4 1/16	4	4 3/16	3 15/16
I	1 1/2	1 3/8	1 1/4	1 3/8	1 1/4	1 11/16
K	5 1/2	5 9/16	5 7/16	5 3/8	5 7/16	5 3/8
L	15/16	1	1 1/8	1 1/32	1 1/8	1 1/16

*Letters refer to Fig. 2.

The areas were taken by means of carbon prints on white tissue paper. The two wheels were hoisted by means of jack screws just enough to allow the insertion of the tissue paper and carbon. The wheels were then carefully lowered and the load applied. When the load was removed the wheels were again hoisted and the paper removed. Areas were taken for loads on each wheel of 5,000, 10,000, 15,000 and 18,000 lbs. No attempt was made to apply loads greater than 18,000 lbs., it being considered the maximum load for the wheels tested. Various methods for taking areas were tried and each one checked up by measurements of known areas. The method described above, previously used by Mr. Geo. L. Fowler ("The Car Wheel,") was found to give the best results and was, accordingly, adopted. All areas were measured with the planimeter.

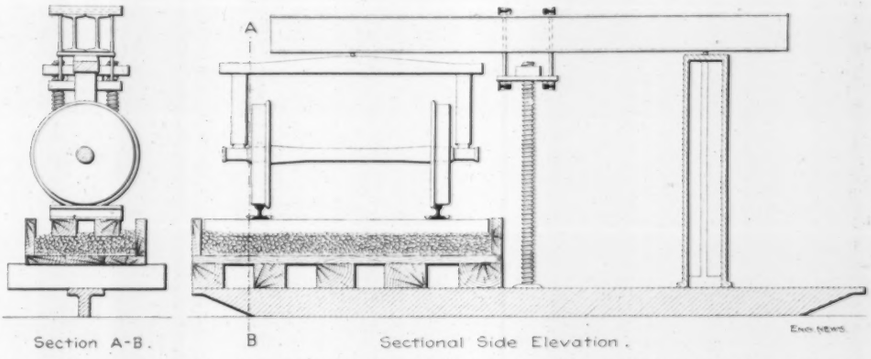


FIG. 3. DIAGRAM SHOWING ARRANGEMENT OF APPARATUS FOR TESTING AREA OF CONTACT BETWEEN CAR WHEELS AND RAILS.

Repeated areas were taken at different points on the tread of the wheel. In order to study the effect of the position of the wheel on the area, contacts were taken in three positions, viz: With the flange against the rail (designated "against") with the opposite flange against its rail (designated here as "flange away") and for a position midway between these two (designated "normal").

Table II shows the average areas obtained by using wheels B, A and D on both the 90-lb. and the 75-lb. rail for different positions and different loads. Table III shows a comparison of areas for wheels A, B and D. It is seen that the steel-tired wheels give greater areas than the cast-iron wheels on the 90-lb. rail and less on the 75-lb. rail. It would be expected that these wheels would give greater areas on each size of rail, since they had a greater diameter. That they did not must be due to the shape of the head of the 75-lb. rail. Table IV shows the areas taken on the wheels C. It should be remembered that C_a is the wheel worn hollow and C_b is the less worn wheel of the pair. From this table it is seen that C_a gives considerably higher averages than C_b for the 90-lb. rail and slightly higher for the 75-lb. rail. Averaging results of C_a and C_b the figures show for the 90-lb. rail areas greatest when "away" and least when "normal," and for the 75-lb. rail greatest when "against" and least when "away." This shows that the flange areas are likely to be as large or larger than the normal areas. The idea commonly accepted is that the flange areas are always small.

Table V shows the averages for all wheels for a load of 18,000 lbs. on each car wheel, for the two rails, and the various positions of the contact areas. For the 90-lb. rail, in the average of all positions on the tread, wheels A give the greatest area, D second, C third and B fourth, or in the order ADCB. For the 75-lb. rail the order is CBAD. The results for the 90-lb. rail are what one might expect, considering the weight and size of wheels and the fact that the wheels C were worn hollow and so capable of giving greater contact. It seems also that wheels C and B had been so worn as to give greater contact on the 75-lb. rail. The condition of the tread of wheels C and the contact with the 90-lb. rail for the normal position are shown in Fig 5. The wheel, C_a, always gave a two-area contact with the 90-lb. rail and a single contact with the 75-lb. rail for the normal position. Typical areas for wheels C are shown in Fig. 6. The maximum pressure has been computed on the assumption that at the center of contact the pressure is twice the average. This does not give the exact pressure, probably, but below the elastic limit it must approximate closely the true pressure.

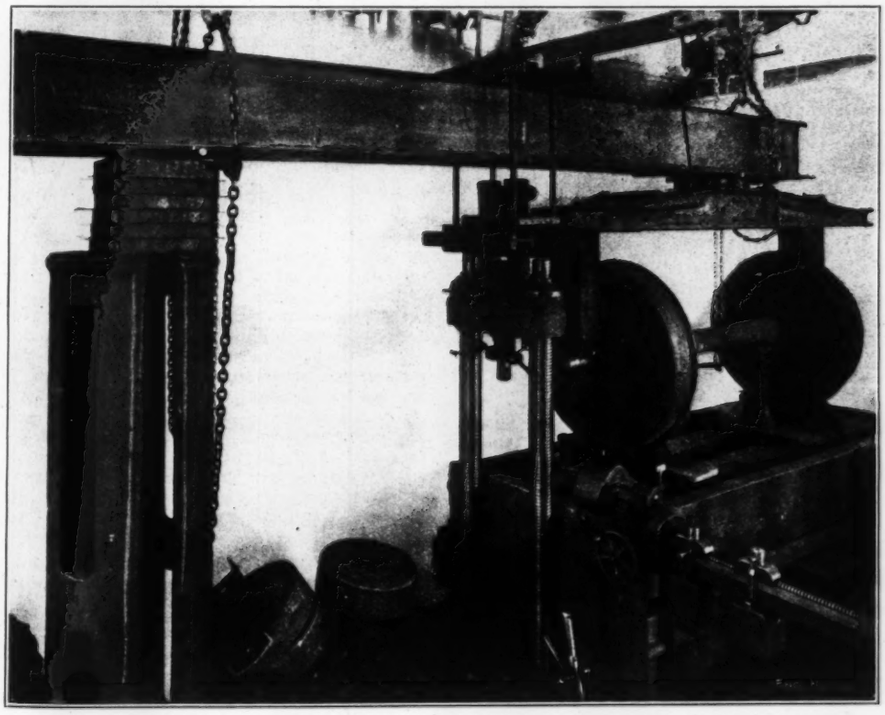


FIG. 4. CAR WHEELS ON TESTING MACHINE IN POSITION FOR TESTING AREA OF CONTACT WITH RAILS.
(Short rails were spiked to two ties ballasted with crushed stone in box on base of testing machine.)

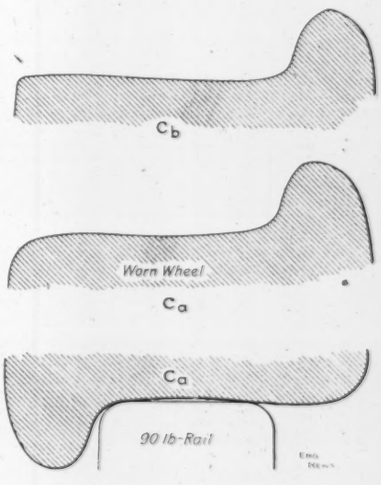


Fig. 5. Condition of Treads of Worn Cast-Iron Wheels "C" and Contact With 90-lb. Rail for Normal Position.

A further averaging of the areas in Table V may be made as follows:

	Total average area, all wheels.	
	90-lb. rail.	75-lb. rail.
Flange against	.51	.383
Flange normal	.48	.385
Flange away	.61	.407
All positions	.51	.394

All wheels, all positions considered, show areas of contact greater for the 90-lb. rail than for the 75-lb. rail, viz., 0.51 sq. in. compared with 0.394 sq. in. The flange "away" from rail gives the greatest area for both rails. The flange "normal" gives least on the 90-lb. rail and the flange "against" on the 75-lb. rail.

In order to determine the effect of the bending of the ties and rails upon the area, the pair D was mounted with the rail sections resting on the base of the machine, after the track section had been removed as shown in Fig. 7. (The chains and ropes shown in Figs. 4 and 7 were always slack during tests and were kept in place to prevent accident). The results of these tests

TABLE II.—AVERAGE CONTACT AREAS FOR WHEELS B, D AND A.

Load, pounds.	Wheels B—Area 90-lb. rail, sq. in.	Wheels B—Area 75-lb. rail, sq. in.	Wheels D—Area 90-lb. rail, sq. in.	Wheels D—Area 75-lb. rail, sq. in.	Wheels A—Area 90-lb. rail, sq. in.	Wheels A—Area 75-lb. rail, sq. in.
			Flange Against.			
5,000....	.29	...	.42	.20	.59	.30
10,000....	.42	...	.47	.25	...	.33
15,000....	.46	...	.54	.33	.54	.42
18,000....	.41	...	.61	.28	.60	.32
			Flange Normal.			
5,000....	.20	.38	.30	.18	.29	.23
10,000....	.25	.36	.38	.20	.37	.25
15,000....	.24	.38	.47	.30	.46	.25
18,000....	.37	.42	.50	.33	.63	.34
			Flange Away.			
5,000....	...	.25	.38	.22	.33	...
10,000....	...	.36	.55	.30	.43	.24
15,000....	...	.39	.60	.32	.58	.30
18,000....	...	.44	.65	.36	.66	.40

TABLE III.—COMPARISON OF CONTACT AREAS FOR STEEL-TIRED AND CAST-IRON WHEELS.

Load, lbs.	5,000	10,000	15,000	18,000	
Cast-iron wheels A and B	.268	.288	.365	.445	90-lb. rail
Steel wheels D	.276	.40	.456	.493	
Cast-iron wheels A and B	.233	.272	.34	.375	75-lb. rail
Steel wheels D	.173	.193	.263	.283	

Note: Areas given are averages for all positions in square inches.

are shown in Table VI and some of the areas in Fig 8. It is seen from this table that the areas given for the 90-lb. rail are considerably greater with ties than with no ties, indicating that the bending of the ties and rails tends to increase the area of contact. There seems to be scarcely any increase, however, for the 75-lb. rail.

The average areas obtained in these tests are considerably higher than those obtained in tests made heretofore, when the same wheel loads were used. In Table VII some typical areas are compared with areas obtained by Fowler ("The Car Wheel") and J. B. Johnson ("Materials of Construction"). The tests made by Fowler and Johnson were made with the rail resting on a

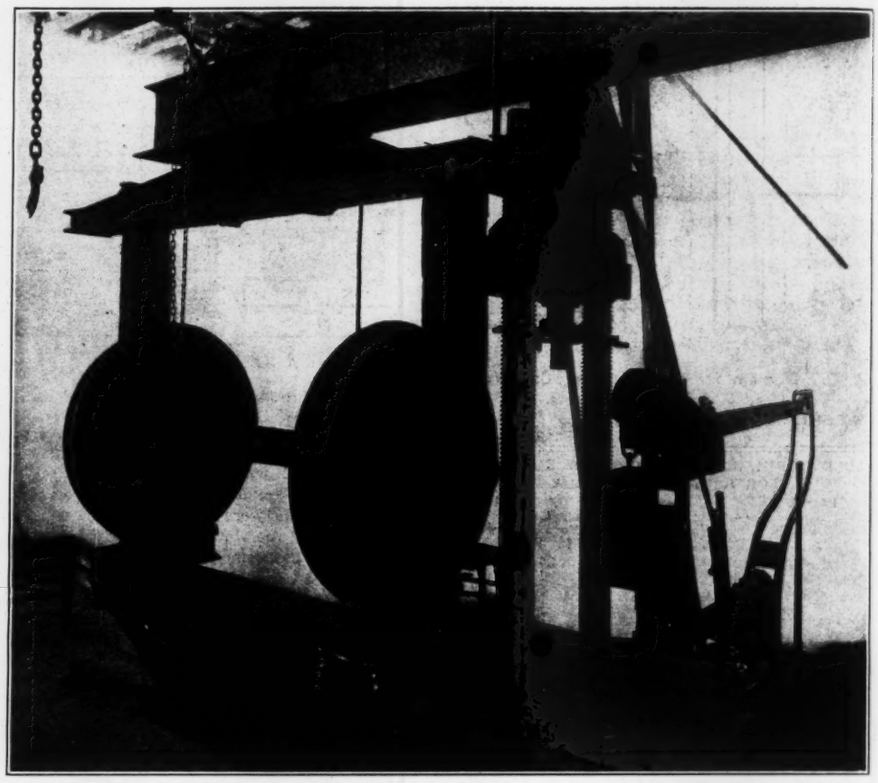


FIG. 7. CAR WHEELS MOUNTED ON TESTING MACHINE TO DETERMINE CONTACT AREA WITH RAILS SOLIDLY SUPPORTED.

(Smaller areas were found in this case than with rails on ties owing to elimination of bending of rails.)

TABLE IV.—AVERAGE AREAS OF CONTACT FOR WORN WHEELS FOR DIFFERENT POINTS ON TREAD.

Load. lbs.	Wheel Ca: Area 90-lb. rail, sq. in.	Wheel Ca: Area 75-lb. rail, sq. in.	Wheel Ca: Stress, lbs. per sq. in. 90-lb. rail.	Wheel Ca: Stress, lbs. per sq. in. 75-lb. rail.	Wheel Cb: Area 90-lb. rail, sq. in.	Wheel Cb: Area 75-lb. rail, sq. in.	Wheel Cb: Stress, lbs. per sq. in. 90-lb. rail.	Wheel Cb: Stress, lbs. per sq. in. 75-lb. rail.
				Flange against.				
5,000	.19	.22	52,600	45,400	...	.23	.....	43,400
10,000	.28	.52	71,400	38,400	.20	.30	100,000	66,600
15,000	.30	.80	100,000	37,400	.28	.34	107,200	88,200
18,000	.52	.71	69,700	50,600	.35	.39	102,800	92,200
				Flange normal.				
5,000	.65	.25	15,380	40,000	.17	.29	59,600	34,400
10,000	.68	.37	29,400	54,000	.21	.40	95,200	50,000
15,000	.60	.40	50,000	70,000	.31	.46	96,800	65,200
18,000	.54	.40	66,600	90,000	.30	.50	120,000	72,000
				Flange away.				
5,000	.28	.24	35,900	41,600	.25	.28	40,000	35,600
10,000	.30	.30	66,600	66,600	.42	.39	47,600	51,200
15,000	.33	.30	90,800	100,000	.62	.49	48,400	61,200
18,000	.38	.34	94,600	111,600	.66	.52	54,400	69,200

Note: Ca = wheel worn hollow; Cb = wheel less worn.

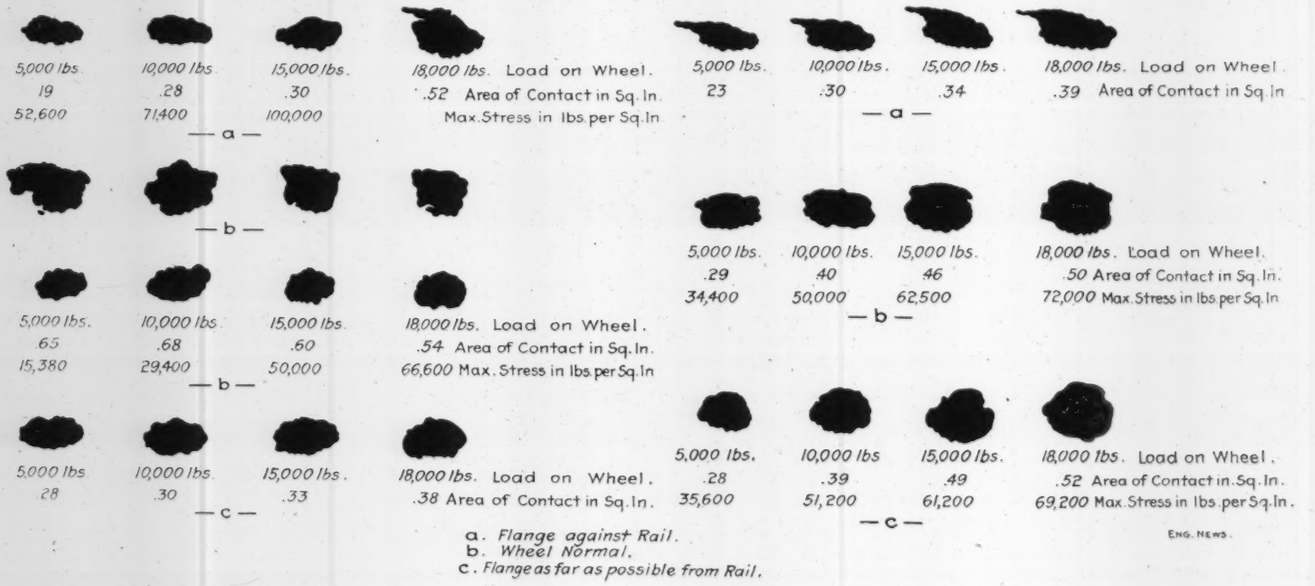

5,000 lbs. 10,000 lbs. 15,000 lbs. 18,000 lbs. Load on Wheel.
19 .28 .30 .52 Area of Contact in Sq. In.
52,600 71,400 100,000 Max. Stress in lbs. per Sq. In
— a —
5,000 lbs. 10,000 lbs. 15,000 lbs. 18,000 lbs. Load on Wheel.
23 .30 .34 .39 Area of Contact in Sq. In
— a —
— b —
5,000 lbs. 10,000 lbs. 15,000 lbs. 18,000 lbs. Load on Wheel.
.65 .68 .60 .54 Area of Contact in Sq. In.
15,380 29,400 50,000 66,600 Max. Stress in lbs. per Sq. In
— b —
5,000 lbs. 10,000 lbs. 15,000 lbs. 18,000 lbs. Load on Wheel.
.29 .40 .46 .50 Area of Contact in Sq. In.
34,400 50,000 62,500 72,000 Max. Stress in lbs. per Sq. In
— b —
5,000 lbs. 10,000 lbs. 15,000 lbs. 18,000 lbs. Load on Wheel.
28 .30 .33 .38 Area of Contact in Sq. In.
— c —
5,000 lbs. 10,000 lbs 15,000 lbs. 18,000 lbs. Load on Wheel.
.28 .39 .49 .52 Area of Contact in Sq. In.
35,600 51,200 61,200 69,200 Max. Stress in lbs. per Sq. In.
— c —
a. Flange against Rail.
b. Wheel Normal.
c. Flange as far as possible from Rail.
ENG. NEWS.
Wheel Ca; 90 lb. Rail, 2 Ties.
Wheel Cb; 75 lb. Rail, 2 Ties.

FIG. 6. RAIL CONTACT AREAS OF WORN CAST-IRON CAR WHEELS.

TABLE V.—AVERAGE CONTACT AREAS FOR VARIOUS PAIRS OF WHEELS FOR LOAD OF 18,000 LBS.

	Wheels B. Average area		Wheels D. Average area		Wheels A. Average area		Wheels C. Average area	
	90-lb. rail.	75-lb. rail.	90-lb. rail.	75-lb. rail.	90-lb. rail.	75-lb rail.	90-lb. rail.	75-lb rail.
Against	.41	...	.61	.28	.60	.32	.435	.55
Normal	.37	.42	.50	.33	.63	.34	.42	.45
Away	...	.44	.65	.36	.66	.40	.52	.43
Average	.39	.43	.586	.323	.63	.35	.458	.476

Note: Areas in square inches.

TABLE VI.—AVERAGE CONTACT AREAS FOR WHEELS D WITH AND WITHOUT TIES.

		90-lb. rail.	75-lb. rail.
Two Ties	Flange against	.61	.28
	Flange normal	.50	.33
	Flange away	.65	.36
	Average	.586	.32
No Ties	Flange against	.38	.31
	Flange normal	.39	.30
	Flange away	.39	.34
	Average	.39	.31

Note: Areas in square inches.

solid base, while in those made by the writer ties were used. The values selected for this table are not average values but they show what might be shown by the selection of other areas, viz.,

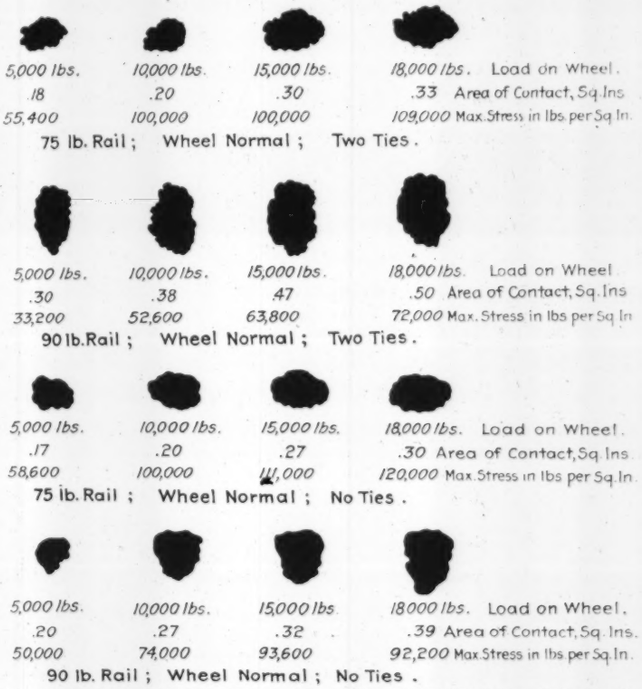

5,000 lbs. 10,000 lbs. 15,000 lbs. 18,000 lbs. Load on Wheel.
.18 .20 .30 .33 Area of Contact, Sq. Ins.
55,400 100,000 100,000 109,000 Max. Stress in lbs. per Sq. In.
75 lb. Rail; Wheel Normal; Two Ties.
5,000 lbs. 10,000 lbs. 15,000 lbs. 18,000 lbs. Load on Wheel.
.30 .38 .47 .50 Area of Contact, Sq. Ins.
33,200 52,600 63,800 72,000 Max. Stress in lbs. per Sq. In.
90 lb. Rail; Wheel Normal; Two Ties.
5,000 lbs. 10,000 lbs. 15,000 lbs. 18,000 lbs. Load on Wheel.
.17 .20 .27 .30 Area of Contact, Sq. Ins.
58,600 100,000 111,000 120,000 Max. Stress in lbs. per Sq. In.
75 lb. Rail; Wheel Normal; No Ties.
5,000 lbs. 10,000 lbs. 15,000 lbs. 18,000 lbs. Load on Wheel.
.20 .27 .32 .39 Area of Contact, Sq. Ins.
50,000 74,000 93,600 92,200 Max. Stress in lbs. per Sq. In.
90 lb. Rail; Wheel Normal; No Ties.

FIG. 8. RAIL CONTACT AREAS OF STEEL-TIRED CAR WHEELS WITH AND WITHOUT TIES.

that the areas obtained by the writer are greater than those obtained by Fowler and Johnson. It is quite likely that the areas obtained by the writer are somewhat higher than those obtained in service, since the bending of the short sections of rail was greater than in service and since the tread of the wheel rolled slightly across the face of the rail due to the bending of the axle when the load was applied. This latter condition does not obtain in service when the axle is constantly under bending. Even when the increased bending of the rail and the bending of the axle are considered, the areas obtained by the writer are still considerably higher than those obtained heretofore, indicating that the bending of the rail and tie increase the area of contact appreciably. This gives a corresponding decrease in the maximum fiber stress.

HOLLOW POLES OF REINFORCED CONCRETE made by a centrifugal process are manufactured in the works of the Deutsche Schleuderröhren Werke at Meissen, Germany. The mold is rotated around its longitudinal axis at high speed after the wet concrete is poured in. The rotation is kept up for about 10 mins., which seems to be sufficient time to allow the concrete to form a uniform shell in the mold and acquire enough hardness to hold its shape. The machine used is similar to a long lathe-bed carrying a number of yokes adapted to surround the form for the pole. These yokes have each three bearing-wheels or rollers, in which runs a clamp ring which engages and holds the form. At several points along the length of the machine there are pulley-and-belt drives, the belts running over the outer surface of the clamp rings. The process of manufacturing the poles is thus: The reinforcement is first prepared. It consists of longitudinal rods held by hooping spirals inside and outside. Small concrete blocks or spacers are wired to the skeleton at numerous points, to center it in the mold. Then the assemblage is placed in the cylindrical or conical form, and a sufficient amount of concrete is poured in, after which the form is slipped endways into place in the centrifugal machine. If the pole is to be cylindrical and of uniform thickness along the whole length, the machine is set so as to bring the form into accurate level. If the form is conical (for a conical pole), a level position will result in greater thickness of concrete at the large end. While this is generally desirable, a uniform thickness may be wanted, and in this case the machine must be tilted so as to hold the small end of the form at a lower level than the large end, in which position the tendency of the material to flow downhill will balance the centrifugal tendency to throw more material toward the large end. Exact adjustment of the angle of tilt must be a matter of experience, of course. The rotation of the mold not only throws the concrete outward to form a shell, but also separates out the excess water, which, being lighter than the concrete, remains inside the latter. The drying action undoubtedly helps in solidifying the concrete quickly. It is found that after 10 to 15 mins. the concrete is solidified enough so that the form can be taken out of the machine and laid away to allow the concrete to set. After a week or so the form is removed, and the pole is then stored on a moist sand bed for two weeks longer.

These poles have shown good strength in bending tests, and they seem to be fairly uniform. They are manufactured in sizes up to 46 ft. long, 6 to 8 ins. at the point and 9 to 15 ins. diameter at the butt, with shell thickness 1¼ to 3½ ins. They are the invention of Prof. M. Foerster, of Dresden, Germany. The process has been patented.

A GATE VALVE, IN A 48-IN EXHAUST LINE of a 1,000-KW. low-pressure steam turbine operated by a 3-HP., three-phase, 60-cycle, 550-volt induction motor, is in operation at the plant of the Pressed Steel Car Co., McKees Rocks, Pa. The motor speed (1,120 r. p. m.) is reduced through spur gears for the proper operation of the thread of the main stem. A hand wheel for hand closing is also provided. A worm gear on one of the intermediate shafts operates a limit-switch mechanism, which automatically controls the movement of the gate by stopping the motor at a certain point in the gate travel, either way.

Applications of alternating-current motors for control services of this kind are yet considered novelties, but the performance of this apparatus is claimed to have demonstrated that the induction motor can do such work for which the direct-current motor has already proven an ideal motive power. To open or close the valve, it is necessary only to throw the operating switch into the corresponding position, starting the motor which continues to run until it is automatically cut off when the end of the valve travel is reached. The valve is thus operated with the minimum trouble, and can be closed or opened at the predetermined safe operating speed as easily as switching on an electric light. The valve mechanism was designed and built by the Pittsburg Valve, Foundry & Construction Co., of Pittsburg. The electrical apparatus was built by the Westinghouse company.

THE STANDARDIZING OF SPECIFICATIONS FOR paving (asphalt, brick and creosoted wood especially) is to be considered at a convention of city engineers and officials which is to be held at Chicago, Feb. 21 to 26. It is believed that better materials, better paving and lower prices will result from the improved specifications. The convention was suggested by the Board of Local Improvements (Chicago) and approved by Mayor Busse, who has issued a notice to this effect to the mayors of cities having a population of 100,000 or over. The Board has had the matter under discussion with the officials of several large cities, who agree that such a convention should produce beneficial results. The arrangements are in charge of Mr. F. P. Fowler, 302 City Hall, Chicago.

THE SOUTH SAN JOAQUIN IRRIGATION DISTRICT in California has voted $1,875,000 of bonds for irrigation works to be constructed in accordance with plans made by Mr. Edwin Duryea, Jr., of San Francisco, Chief Engineer of the district. The bonds carried by a popular vote of 329 to 67. The district comprises about 62,000 acres of land in the southern part of San Joaquin County, but it is expected that it will be enlarged to 70,000 acres. The district is organized under what is known as the Wright-Bridgeford Law, which enables irrigation districts to issue 30-year 5% bonds to pay for the cost of works. The bonds are redeemable between the 20th and 30th year of their life, unless the district votes to refund the bonds. All the land in such an irrigation district is taxed to pay the interest and maintenance charges, and finally the redemption charges of the bonds. Mr. Duryea has provided for a drainage system in connection with the above-named irrigation works, to control the underground water-level and prevent injurious effects due to ultimate saturation of surface soil.

THREE-CYLINDER TANK LOCOMOTIVES for heavy switching service have been built at the Gateshead shops of the Northeastern Ry. (England), to the designs of Mr. Wilson Worsdell, M. Inst. C. E., Chief Mechanical Engineer. The engines are of a class used in gravity switching yards, where trains have to be pushed up a grade to the "hump" or summit of the gravity tracks. It is of the 4:8:0 class, with side tanks and a rear coal bunker. The cylinders are all in line, at the smokebox, and are served by three piston valves, the three pairs of eccentrics for which are all mounted on the first driving axle. The inside cylinder is connected to the first driving axle, while the outside cylinders drive the second driving axle. The cranks are set at 120°, in order to give a more uniform turning moment than can be obtained with two or four cylinders. The general dimensions are as follows:

Wheels, driving	4 ft. 7¼ ins.
Wheels, truck	3 ft. 1¾ ins.
Wheelbase, driving	15 ft. 3 ins.
Wheelbase, total	29 ft. 0 ins.
Weight on driving wheels	149,730 lbs.
Weight, total	189,600 lbs.
Boiler, diameter	4 ft. 9 ins.
Tubes, No. 225; diameter	1¾ ins.
Tubes, length	11 ft. 4½ ins.
Firebox, inside	7 ft. 4 ins. × 3 ft. 3 ins.
Steam pressure	175 lbs.
Cylinders (3)	18 × 26 ins.
Piston valves (3), diameter	8¾ ins.
Ports, width	1¾ ins.
Valves, travel	4¼ ins.
Valves, cap	15/16-in.
Connecting rod, inside, length	6 ft. 7 ins.
Connecting rod, outside, length	9 ft. 6 ins.
Heating surface, tubes	1,169 sq. ft.
Firebox	141 sq. ft.
Total	1,310 sq. ft.
Grate area	23 sq. ft.
Water in tanks	2,500 Imp. gals.
Coal in bunker	4¼ tons
Rail to center of boiler	8 ft. 2 ins.
Rail to top of smokestack	13 ft. 1 in.

TABLE VII.—COMPARISON OF CARWHEEL CONTACT AREAS OBTAINED BY DIFFERENT INVESTIGATORS.

Load, lbs.	Fowler steel wheels, 80-lb. rail.	Hancock steel wheels, 75-lb. rail. With tie.	Hancock steel wheels, 75-lb. rail. No tie.	Fowler steel wheels, 100-lb. rail.	Hancock steel wheels, 90-lb. rail. With tie.	Hancock steel wheels, 90-lb. rail. No tie.	Fowler cast-iron wheel, 100-lb. rail.	Johnson cast-iron wheel, 75-lb. rail.	Hancock cast-iron wheel, 75-lb. rail.	Hancock cast-iron wheel, 90-lb. rail.
5,000	.08	.18	.20	.08	.30	.20	.11	.08	.38	.20
10,000	.10	.20	.25	.14	.38	.27	.12	.12	.36	.25
15,000	.15	.30	.28	.17	.47	.28	.16	.16	.38	.24
20,000	.23	.33	.34(18,000 lb.)	.19	.50	.38(18,000)	.18(17,500)	.21(18,000)	.42(18,000)	.37(18,000)

Note: Areas in square inches.

Track Elevation at Evanston, Ill.; Chicago, Milwaukee & St. Paul Ry.

By E. O. GREIFENHAGEN.*

The Bridge & Building Department of the Chicago, Milwaukee & St. Paul Ry. (under the direction of Mr. C. F. Loweth, M. Am. Soc. C. E., Engineer and Superintendent), is completing some interesting construction work in connection with grade separation in Evanston, Ill. The work presented a number of difficult problems and a description of the solutions proposed and of those adopted, together with a discussion of the reasons for the choice made, will be of interest.

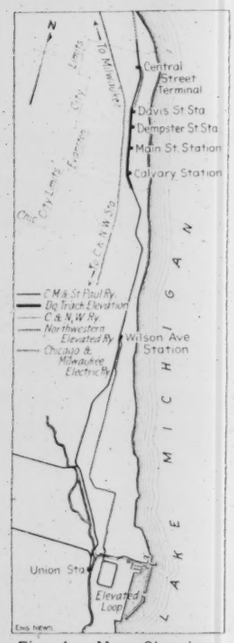


Fig. 1. Map Showing Track Elevation Work and Electric and Elevated Railway Connections of the Chicago, Milwaukee & St. Paul Ry. at Evanston, Ill.

The city of Evanston extends about four miles along the shore of Lake Michigan just north of the city limits of Chicago. It has a population of nearly 30,000 and is almost exclusively a residence town. The Chicago & Evanston Division of the Chicago, Milwaukee & St. Paul Ry. runs from the Union Station, Chicago, through the north shore suburbs and Evanston to Wilmette, just north of Evanston, a total distance of about 14 miles. This line handles a considerable freight traffic and formerly took care of a certain amount of suburban passenger traffic. The Chicago terminal, however, is not very convenient to the main business, shopping and theater center, which lies within the loop made by the elevated railways.

The Northwestern Elevated Ry. originally extended from the downtown loop to Wilson Ave., 6½ miles, and its terminal was at the Wilson Ave. station on the Chicago & Evanston Division of the C., M. & St. P. Ry. (shown in Fig. 1). The elevated railway had long desired an extension to Evanston, and in August, 1907, it obtained a lease from the C., M. & St. P. Ry. which allowed it to run its trains on the latter's right of way from Wilson Ave. to Central St. (Evanston), 7.2 miles. This part of the line was modified for electric traffic, and on May 16, 1908, trains were run from the loop in Chicago to the north end of Evanston, a distance of about 13.7 miles. The C., M. & St. P. Ry. tracks north of Central St. are used by the Chicago & Milwaukee Electric Ry., which parallels the Northwestern Elevated Ry. down to Church St.

The right of way of the Chicago & Northwestern Ry. adjoins that of the Chicago, Milwaukee & St. Paul Ry. from near the southern boundary of Evanston to Davis St., which is one block south of the limit of the track elevation. The very heavy traffic on the former line and the frequency of the electric trains on the latter line made it difficult to prevent accidents at the numerous street crossings. The unusual conditions brought about by the proximity of the railways led the city and the two railway companies to agree upon grade separation. An ordinance was passed in March, 1907, by which the Chicago, Milwaukee & St. Paul Ry. was required to elevate its tracks from the southern boundary of the city to Church St., which is at the north end of the business district. The embankment was to be as wide as desired by the company, provided it was retained within the right of way by suitable walls. The ordinance for the Chicago & Northwestern Ry. was similar.

Subway Problem.

The bridges which carry the tracks over the streets are the most important features of track elevation work for the reason that (1) they control the elevation of the base of rail and consequently the profile of the line; (2) they furnish the largest separate items of cost in such work, and (3) they are constantly before the eyes of the public. These three matters were considered when the question of the type of structure for the Evanston subways was taken up, and it was endeavored to design bridges which would have: (1) floors as thin as practicable, to make the elevation of the tracks a minimum; (2) initial cost as small as possible consistent with durability and economy in maintenance, and (3) a good appearance and qualities which would render them noiseless and as nearly waterproof as possible. That part of the ordinance referring most directly to the construction of the subway bridges reads as follows:

> Bridges of one or more spans; the superstructure of which shall consist of iron or steel girders with a continuous floor. Provision shall be made to prevent storm water, dirt, oil and other substances from dropping into the subways. The bridges shall be supported upon abutments of concrete, stone, or brick masonry, or on rows of iron or steel columns, braced together laterally, and erected on and anchored to masonry foundations constructed within the lines of the railway company's right-of-way, and in the centers and curb lines of the intersecting avenues and streets.

This clause was considered rather vague and was inserted more for the purpose of eliminating wooden or temporary construction and non-continuous floors than for the purpose of binding the railway to any particular design. Consequently it was decided to estimate on various types of steel, reinforced concrete, and combination bridges, which might fit the conditions and comply with the spirit of the ordinance. The 14 subways come under two general classes: (A) Seven subways whose greatest span is 26 ft. or less. All but one of these subways have the roadway divided into two spans by a pier in the middle of the street. (B) Seven subways whose greatest spans vary from about 30 ft. to about 36 ft. None of these subways have piers in the middle of the roadway.

In making the preliminary estimates, these two classes were considered separately, on account of the difference in length of span. As representing the class (A) subways, Grove St. was chosen. This was to have two 10-ft. sidewalks and a 46-ft. roadway, with piers allowed at the curb lines and at the middle of the street, making a four-span crossing. As representing class (B) subways, Greenwood St. was chosen. This was to have 10-ft. sidewalks and a 36-ft roadway, with piers allowed at the curb lines only, making a three-span bridge.

There were five schemes drawn up and estimated for the Grove St. subway as follows: (A-1) Reinforced concrete slabs, 13 ft. wide, supported by reinforced concrete piers, each pier having four columns. (This was very similar to the adopted design, Fig. 6, but with flat-topped slabs, and with roadway spans 24½ ft. c. to c. of columns instead of 21¼ ft.—Ed.)

(A-2) I-beam deck spans (eight 20-in. I-beams per track for roadway spans) with a reinforced concrete ballasted deck supported by structural steel bents with two columns each (Fig. 2). (A-3) I-beam deck spans (four 24-in. I-beams per track for roadway spans) with reinforced-concrete ballast deck and ornamental reinforced concrete parapets or facia girders, supported by steel bents as above. (A-4) Through plate-girder spans with floor composed of 15-in. I-beams spaced about 18 ins. c. to c. and covered with a reinforced-concrete ballast deck; girders supported by structural steel bents or piers of three columns each. (A-5) Through plate-girder spans with I-beam floor, similar in design to (A-3), except that the curb piers are omitted and the girders span from the abutments to the middle pier.

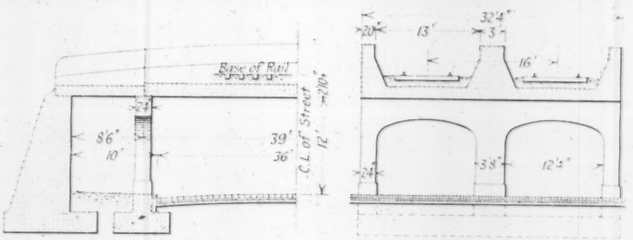


FIG. 3. ALTERNATIVE DESIGN FOR SUBWAY BRIDGES (REINFORCED-CONCRETE THROUGH SPANS ON CONCRETE PIERS); C., M. & ST. P. RY.

Six designs were drawn and estimated for the Greenwood St. subway (class B) as follows: (B-1) Through bridge composed of heavy reinforced-concrete girders, with a concrete ballast floor spanning between them; the girders supported by reinforced-concrete piers, each having three columns; Fig. 3.— (B-2) Through plate girder spans with I-beam floor composed of 12-in. I-beams spaced 15 ins. c. to c. with a continuous reinforced-concrete ballast deck; girders supported by steel bents with three columns each; Fig. 4.— (B-3) Through plate girder spans with steel floor beams and stringers, and a reinforced concrete ballast deck; girders supported by steel bents of three columns each.—(B-4) Bethlehem girder-beam deck spans (six 26-in. beams per track for roadway spans) with a reinforced-concrete ballast deck; supported by steel bents of two columns each; Fig. 5.— (B-5) Similar to (B-4) except for the addition of ornamental concrete parapets or facia girders.—(B-6) Span made up of two 30-in. Bethlehem girder-beams per rail; rails set down between pairs of beams and supported by a concrete floor; spans supported by steel bents of two columns each.

All the above schemes were estimated for a double-track bridge, exclusive of track, abutments, falsework, depression of street, paving, and all other items which were common to every type considered, and which, therefore, would not affect their relative costs. Natural foundations were assumed in all cases. It was found that pile foundations would add about 10% to the estimates. Table I. shows the relative

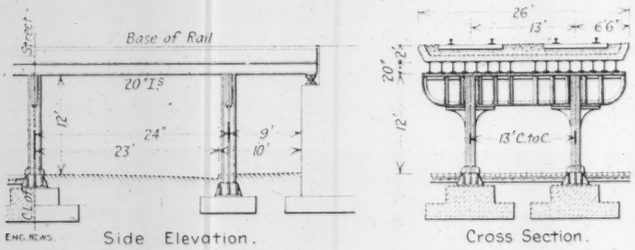


FIG. 2. ALTERNATIVE DESIGN FOR SUBWAY BRIDGES (CONCRETE DECK ON I-BEAMS AND STEEL BENTS); C., M. & ST. P. RY.

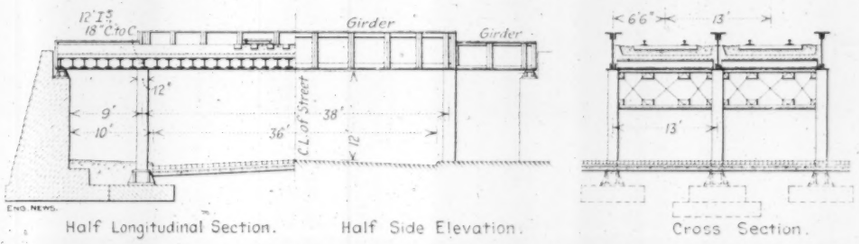
TABLE I.—COMPARISON OF BRIDGE DESIGNS FOR SUBWAYS.

Scheme	Depth of floor. Ft.	Ins.	Ratio of cost.	Scheme.	Depth of floor. Ft.	Ins.	Ratio of cost.
A-1	4	0	100	B-1	2	10	104
A-2	3	8	112	B-2	2	10¾	150
A-3	4	0	108	B-3	3	9½	134
A-4	3	5½	146	B-4	4	2	134
A-5	3	5½	149	B-5	4	2	136
				B-6	2	0	132

*Office Engineer; Bridge and Building Department; Chicago, Milwaukee & St. Paul Ry., Railway Exchange, Chicago.

sts and depths from base of rail. The cost of cheme (A-1) being the lowest, is called 100.

The depths of the floors are second only to the rst cost of the bridge in their bearing on the tal cost of the track elevation work, and they ere fully considered in the choice of the final ypes. A list of the advantages and disadvanges of each of the schemes was also studied in



Half Longitudinal Section. Half Side Elevation. Cross Section.

FIG. 4. ALTERNATIVE DESIGN FOR SUBWAY BRIDGES (PLATE GIRDER THROUGH SPANS ON STEEL BENTS); C., M. & ST. P. RY.

connection with the features in the table, and as the result of the investigation it was decided to eliminate schemes (A-3), (A-4), (A-5), (B-3), (B-5), and (B-6). A summary of the reasons for eliminating these schemes may be of interest.

Scheme (A-3) was considered less satisfactory than (A-2) because of its greater depth and because the permanence of the false concrete facia girders under the action of deflection and vibration was questioned. Schemes (A-4), (A-5), and (B-3) were discarded because their heavy first cost was not compensated for by a shallow floor and because the girders projecting above the track level were considered undesirable. Scheme (B-5) was replaced by (B-4) in the final estimates because there was little difference in the two designs. Scheme (B-6) was ruled out because of its non-continuous floor and because of the unsatisfactory roadbed which it provided. This left two schemes for the class (A) subways and three for the class (B) subways. The relative costs and depths of floor for these are given below:

Scheme.	Depth of floor. Ft.	Ins.	Ratio of cost.
A-1	4	0	100
A-2	3	8	112
B-1	2	10	104
B-2	2	10¾	150
B-4	4	2	134

Since the depth of the floor controlled the gradient of the track and the amount of fill required, it was necessary to figure the value of this effect before the cheapest combination of schemes for the two classes of crossings could be ascertained. Accordingly, calculations were made to determine the amount of fill and the yardage in retaining walls as well as the effect on the gradients, for several combinations. The combination of all-concrete bridges, (A-1) and (B-1), required from 4,500 to 13,000 cu. yds. of fill and from 320 to 540 cu. yds. of concrete less than any other combination. These facts, together with the figures of costs, showed conclusively that reinforced-concrete bridges for all subways had the least first cost from all points of view. The advantages for the concrete bridges, exclusive of first cost, as compared with the structural steel bridges, were classified as follows:

Advantages Claimed for Concrete Bridges: (1) Greater economy; (2) greater rigidity and freedom from vibration, noiselessness; (3) durability, practically permanent; (4) require almost no maintenance; (5) of good appearance, as befits bridges in a residence town; (6) built entirely of the same materials; footings, abutments and piers can be put in by the same forces, with the same plant; (7) all work can be done by the railway.

Advantages Claimed for Steel Bridges: (1) The strength of the structures can be definitely determined by a field examination, in case the plans are destroyed; (2) ordinary errors of workmanship will not affect the stability of the structure; (3) alterations not impossible; (4) bridges will always have some salvage value; (5) ordinance need not be amended, as would probably be the case if concrete superstructure were adopted; (6) do not require the spreading of the tracks to clear the middle girder, as in the concrete bridges with through girders.

It was decided that the concrete bridges would be more desirable, and steps were taken to obtain the approval of the Evanston authorities for reinforced-concrete superstructure. At the same time, the city developed a sentiment for wider subways than specified in the first ordinance. The railway had found that the bridges over streets which required long clear spans were more costly per lineal foot than the bridges over wider streets which allowed piers in the middle of the roadway, and also that the former would not permit the use of deck slabs (scheme A-1). Consequently, when the city suggested a new schedule of subways, including some wider streets with middle piers, the company agreed to the change. An amendment to the original ordinance was passed in February, 1909, permitting the use of reinforced-concrete bridges and containing the revised schedule of subways, as in Table II.

The new subway bridges had shorter spans throughout than the bridges for which the original estimates were made, and investigation showed that the saving in grade in favor of the concrete bridges was reduced on account of the new conditions, which required slabs throughout. The other advantages of concrete bridges were greatly enhanced, however, because such a type of construction is well adapted to short spans.

The Design of the Subway Bridges.

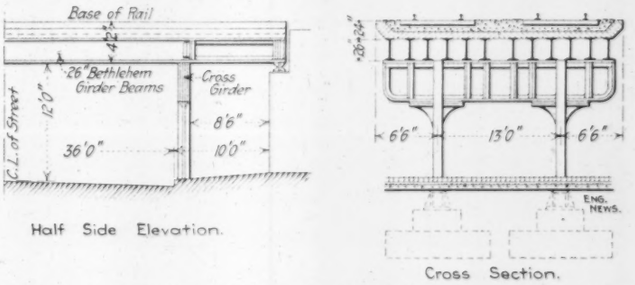
LOADING.—The standard loading for permanent work on the C., M. & St. P. Ry. (east of the Missouri River) is Cooper's E-50. The question was raised as to whether lighter loading might not be considered on the Evanston Division, as the loading consists of electric trains and freight engines; the engines being equivalent to about E-40 loading on spans of 10 to 20 ft. There was a possibility of the future use of electric locomotives for passenger trains. Consequently, estimates were made on three types of loading: Cooper's E-50 and E-40, and a 100-ton electric locomotive similar to the New York Central Ry. type. A typical subway bridge was chosen and the costs for the bridge under these three loadings were estimated to compare as 100, 96 and 96, respectively.

An inspection of these relative costs showed that it would be decidedly poor judgment to design such permanent work for light loading, especially when future changes in rolling stock could not be foretold. All work was designed for Cooper's E-50 loading.

FOUNDATIONS.—In order to determine the conditions, test pits were dug and wash borings made at each crossing. The pits were carried down only far enough to ascertain the depth to ground water, and the kind and condition of the upper strata. The wash borings were made to a depth of 50 ft. in some cases, a ¾-in. pipe within a 2-in. casing pipe being used. These showed varying strata of sand and gravel, with some quicksand. Intermediate pits showed that foundation conditions varied more or less uniformly from one end of the work to the other. On the basis of this information, natural footings were used at 1¾ to 2 tons per sq. ft. for the bridges at Greenleaf St. and all streets south, and pile foundations were used north of this crossing. A bearing on piles of 12 to 16 tons was allowed. The design of the foundations is described below. The carrying of columns down to bed rock or into firm clay on concrete cylinders was considered, and found to be unwarranted by the conditions.

GENERAL LAYOUT.—Fig. 6 shows the Chicago Ave. subway bridge as built. This is typical of the bridges throughout the track elevation. This subway is on a skew of 48° 34' and has two 10-ft. sidewalks and a 40-ft. roadway. A middle pier divides the roadway into two channels. Curb piers are allowed within the sidewalk space. The face of the abutments and wing walls is on the street line. The elevation of the sidewalks at the curb line is the same as that of the crown of the street and the sidewalks slope ¼-in. per ft. upward toward the abutments.

The requisite massiveness of the bridge, due to the heavy loading and the nature of the material employed, limited the architectural treatment to the simplest lines. The slabs which carry the tracks over the various openings between the abutments and piers are provided with parapets of uniform depth and width over the entire crossing. The surface of the parapet is relieved by simple rectangular recessed panels. The abutments are of heavy construction and give the effect of solidity to the end supports. The piers were designed to provide the necessary size and at the same time create an impression of lightness and gracefulness which would relieve any tendency toward a tunnel-like appearance in the subways. The widening of the piers below and above the columns, and the introduction of the curved brackets, have an advantage from a structural as well as an esthetic standpoint. The general appearance of the completed subway bridges may be seen from Fig. 7.



Half Side Elevation. Cross Section.

FIG. 5. ALTERNATIVE DESIGN FOR SUBWAY BRIDGES (GIRDER I-BEAM DECK SPANS ON STEEL BENTS); C., M. & ST. P. RY.

DESIGN OF PIERS.—There are three piers for each subway, except at Mulford St., which has only one span over the roadway. The side or curb piers are placed with the outer face 6 ins. behind the curb line, and the middle piers are placed on the center line of the roadway. The details of the Chicago Ave. piers are shown in Fig. 8. In general, each pier consists of four columns supporting a cross girder and carried by a footing girder which distributes the load to a footing slab.

The top girder, capping the columns, is given an arched form and figured as a continuous beam. The arches provide curved brackets which stiffen the columns laterally and which

TABLE II.—SCHEDULE OF SUBWAYS ON EVANSTON TRACK ELEVATION, C., M. & ST. P. RY.

Subway.	Total width between abutments, ft.	Width of each sidewalk, ft.	Width of each roadway, ft.	Headroom, ft.	Skew, deg.	mins.
Chicago Ave.	60	10	20	13	18	34
Mulford St.	40	10	20*	12	17	49
Rinn St.	60	10	20	12	8	29
Madison St.	60	10	20	13	10	0
Washington St.	60	10	20	12	10	20
Main St.	66	13	20	12	21	13
Greenleaf St.	60	10	20	12	10	36
Dempster St.	66	13	20	12	10	36
Greenwood St.	66	13	20	12	11	53
Lake St.	66	13	20	12	15	19
Grove St.	66	13	20	13	20	38
Davis St.	80	14	26	12	8	28
Church St.	68	14	20	12½	0	2

*Mulford St. has only one roadway span; all the others have two.

give depth to the beam at the points of greatest shear. There are two 1-in. bars in the top of the girder running the full length of the pier, and an additional pair of 1-in. bars over each column, bent down to assist in taking care of web stresses. There are four 1-in. bars in the bottom of the beam running the full length of the pier. Six to eight ½-in. square stirrups bent in W shape are placed in the beams between columns, and three such stirrups in each

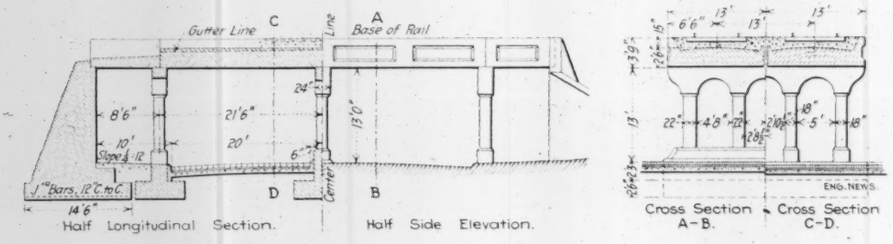


FIG. 6. ADOPTED DESIGN FOR SUBWAY BRIDGES ON THE EVANSTON TRACK ELEVATION; CHICAGO, MILWAUKEE & ST. PAUL RY.

side cantilever. The curved brackets are reinforced by pairs of 1-in. diagonal bars.

The top girders are made 6 ins. wider than the columns; this makes their width 24 ins. in all cases, except 30 ins. at the middle pier at Davis St. The depth of the beam at the crown of the arch varies from 18 ins. to 24 ins. The ends of the cantilevers are cut off perpendicular to the center line of the pier and the concrete slabs are allowed to project beyond the extreme corner, which gives a better appearance and a more satisfactory detail than would be obtained if the ends were made parallel and flush with the slab parapets. The arrangement adopted eliminates the sharp corner and warped surface.

The column shafts from the springing line of the top arches to the top of the base or pedestal vary in height from 6 ft. to 7 ft. 3 ins. The top of the base or pedestal is 1 ft. 11½ ins. above the top of the curb or crown of the street. In the curb piers this pedestal has its horizontal dimensions 6 ins. greater than the column shaft. In the center piers the pedestals are replaced by a continuous base or wheel-guard with a starling at each end.

The columns are reinforced with about 1.5% of steel, consisting of 1-in. vertical bars held in place by ties of ½-in. bars spaced 12 ins. vertically. The main column bars extend from the construction joint at the level of the crown of the roadway to the top of the top girder. Each of these bars is wired to a footing bar which extends from the bottom of the footings to a height of 4 ft. 6 ins. above the construction joint, thus furnishing continuous reinforcement from the bottom to the top of the piers to provide for any bending moment. The concrete columns are 18 ins. wide perpendicular to the center line of the roadway, except that in the center pier at Davis St. they are 24 ins. wide. The curb columns are either 18x20 ins. or 18x22 ins.; the center pier columns are 18x24 ins. At Davis St. the curb columns are 18x24 ins., and the center columns are 24 ins. square. The maximum stress on the column section is about 450 lbs. per sq. in.., including impact.

A footing beam 27 ins. deep distributes the load of the columns to the footing slab. The top of this beam is reinforced by ¾-in. bars extending the full length of the pier, and a number of ¾-in. stirrups tie it to the footing slab. This slab is 30 ins. deep and varies in width according to the bearing area required to keep within the allowable unit pressure on the foundations. It is reinforced by transverse 1-in. bars. Four to five ¾-in. bars are placed longitudinally in the bottom of the footing to provide for possible inequalities in pressure brought about by variations in the foundation conditions, and to take any negative moment which might occur indirectly beneath the columns or in the side cantilevers.

The concrete for the piers is a 1:2½:5 mixture, with 1:2:4 for the columns. Square corrugated bars were used.

ABUTMENTS.—The abutments are of the ordinary massive plain concrete construction, of gravity section above the footing, and have sufficient width of footing to keep the pressure within the allowable limit. Reinforced concrete abutments were not considered because it was expected that this work would be done during freezing weather. The abutments were figured for earth pressure (according to Rankine's theory) for a live load surcharge of 10,000 lbs. per lin. ft. of track spread over a width of 13 ft. and for the reaction of the slab spanning the sidewalk.

The design without piles is shown in Fig. 6. The north abutment at the Chicago Ave. subway is 21 ft. 6 ins. high from bottom of footing to base of rail, and has a base of 14 ft. 6 ins., making a ratio of base to height of 0.67. The footing has a toe projection of 5 ft., reinforced by 1-in. bars. The step is added to keep the unit shear low and make shear reinforcement unnecessary. Fig. 9 is a cross section of the north abutment at Church St., which is on piles. The row of piles are so spaced that the load on the front and rear rows will not exceed the allowable bearing value for the maximum and minimum lateral forces, respectively. For average conditions the bearing on all piles is practically the same.

A seat is provided near the top of the abutments for the sidewalk slabs. On either side of this seat the abutments are carried up level with the tops of the slab parapets and base of rail. The abutments which adjoin those of the Chicago & Northwestern Ry. subways have a slight batter on the front face and a coping under the bridge seats, in order that the structures for the two railways might be similar. The abutments for the other subways are made with vertical faces and without coping.

The wing walls are carried out along the street sufficiently far to prevent the slopes from encroaching on the sidewalks. The tops of the wing walls are sloped down 1 in 1½ to a height of 7 ft. above the ground and are then carried level to the end to match the 7-ft. fences. All abutments are designed with a view to providing for a future third track. The footings are built to the full width on the side upon which the future track will come and the wings are stepped down in such a way as to make the addition of future network practicable.

DESIGN OF SLABS.—Each track is carried over each span by a single reinforced-concrete slab about 13 ft. wide. The roadway openings at Davis St., however, are spanned by two slabs per track, as described later. As all of the subway bridges are on a skew, the slabs take the shape of parallelograms with their sides parallel to the direction of the track and their ends parallel to the center line of the street. The outside parapets of the track slabs are carried up to the level of the base of rail. The faces of the slabs are paneled as shown in Figs. 6 and 7. The inside parapets are made low and merely serve as curbs for the gutters.

The slabs are designed for a live load equivalent to Cooper's E-50 loading, plus impact, and for the dead load of track, ballast, and concrete. It was assumed that the entire load would distribute over the full width of 13 ft. The presence of 15 to 28 ins. of ballast and the transverse reinforcement, as well as the large ratio of the thickness of the slabs to their width, makes this a safe assumption. The longitudinal tension reinforcement consists of a double row of 1-in. bars laid in a direction parallel to the track and spaced as shown in Fig. 8. The shear reinforcement consists of ½-in. U stirrups, assisted by the bent-up ends of a number of the longitudinal bars. The transverse reinforcement consists of ½-in. bars spaced as shown. Inverted U-shaped stirrups for handling are embedded at each end, parallel to the track, and passing through the center of gravity of the slab. A rectangular depression around these stirrups gives roon for the lifting device. The ends of the stirrups are bent horizontally for a distance of 1 ft. Seven ¾-in. bars placed transversely in both the top and bottom of the slabs at each stirrup take care of cross-bending stresses which occur during the handling of the slabs.*

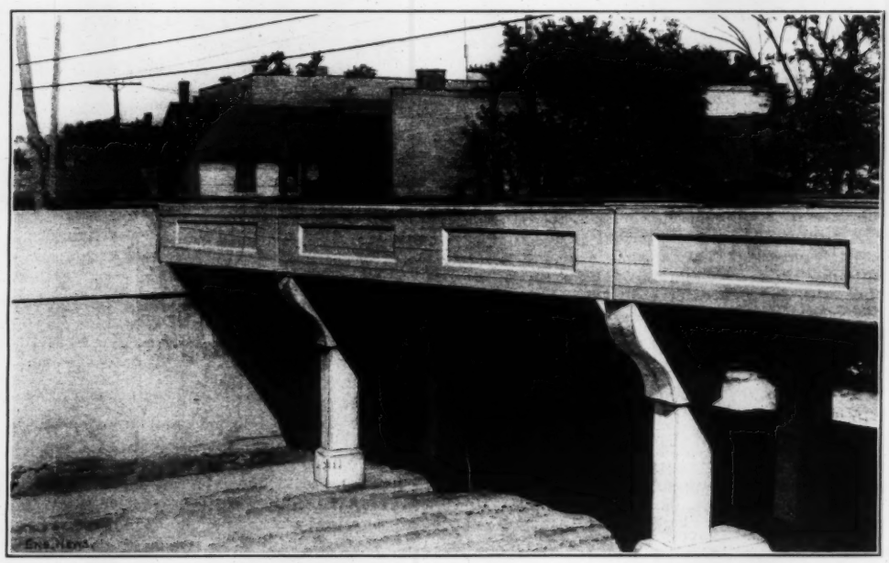


FIG. 7. REINFORCED-CONCRETE SUBWAY BRIDGE AT LAKE ST., EVANSTON; C., M. & ST. P. RY.

The roadway slabs 13 ft. wide vary in thickness from 2 ft. 5 ins. to 3 ft. 5 ins., making the thickness of the bridge floor from bottom of the

*The slab spans of the Illinois Central Ry. track elevation work were illustrated in our issue of Aug. 6, 1900.—Ed.

slab to base of rail from 3 ft. 8 ins. to 4 ft. 10 ins. The sidewalk slabs vary in thickness between 18 ins. and 19 ins. The roadway slabs are given a crown of 2 ins. under the center line of track, which provides for a gutter at each side with a minimum depth of 2 ins. These gutters

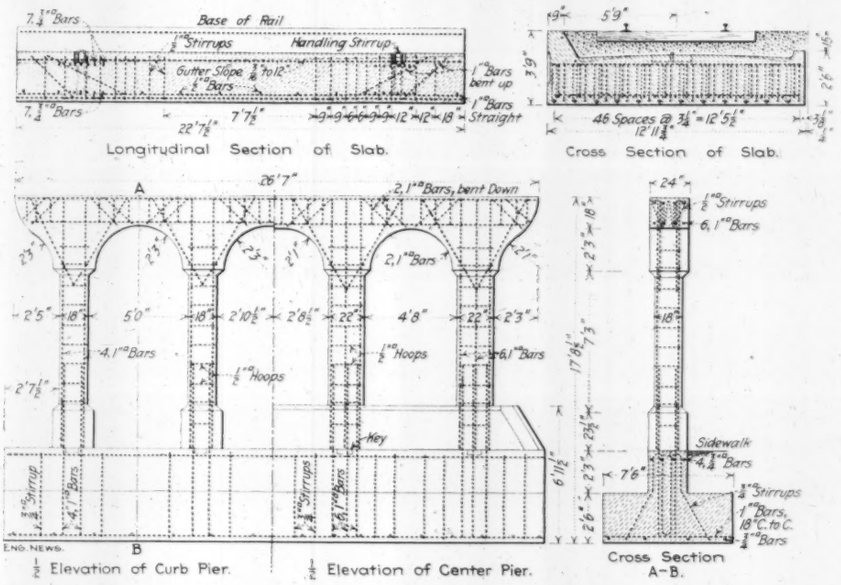


FIG. 8. DETAILS OF REINFORCED-CONCRETE SLAB SPANS AND PIERS FOR SUBWAY BRIDGES.

are sloped from the center line of the bridge toward the abutments. The sidewalk slabs are sloped 3 ins. between the curb piers and the abutments. This arrangement provides for draining the entire bridge floor in each direction from the center line of the street over the back of the abutments. The joints between the sidewalk and roadway slabs are to be sealed and waterproofed in such a manner that the water will pass over them. The section shows the arrangement of slabs and direction of drainage.

The roadway slabs at Davis St. have an overall length of 27 ft. 6 ins., and it was found that a single slab 13 ft. wide would be too heavy to handle; consequently, two slabs were used, each 6 ft. 6 ins. wide. A difficulty was encountered

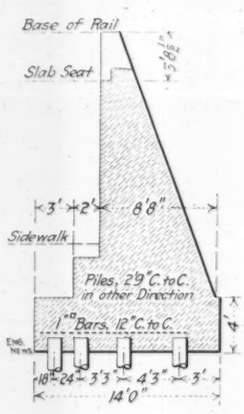


Fig. 9. Abutment on Pile Foundations.

in the design of these slabs due to the fact that the resultant of the live load does not pass through the longitudinal center line of the half slab. On account of this fact the intensity of the reaction near the inner edge was increased, making it necessary to provide for a greater moment at this edge than at the outer edge. This variation of moment was taken care of partly by varying the cross section, partly by varying the per cent. of reinforcement, and partly by adding compressive reinforcement.

Construction of Subway Bridges.

PIERS AND ABUTMENTS.—The building of the piers and abutments was difficult on account of the narrow right of way (in some cases only 40 ft.), the frequency of the electric trains on the double-track line, and the presence of the overhead trolley wires. The trains were operated at 10-minute intervals for the greater part of the day and night, the only respite being between 2 a. m. and 5 a. m., when the interval was increased to 1 hour.

All excavation, driving of foundation piles, and placing of concrete footings was done, so far as possible, before the construction of the falsework bridges and before the raising of the grade. The track was carried across the pits on wooden stringers. The foundation piles were of oak or tamarack 24 to 30 ft. long. The standard track driver was employed and it was necessary to operate the trains single track while the driver was in position to work. The trolley wires were thrown aside as much as possible and the interfering span wires removed. Two pile-drivers were used, and day and night shifts were kept busy. The night crew drove the piles farthest from the center line of track, because in driving these the driver interfered with both tracks.

Pile trestles were put in over all crossings to carry traffic during the erection of the forms and the placing of the concrete for abutments and piers.

It was found impracticable to use sectional forms for the piers to the extent planned, and only the forms for the column shafts and the centers for the arches were designed to be interchangeable. The sheeting for the column bases and the top girders was built in place. All sheeting was placed with joints horizontal and was composed of 2x8 in. lumber. Fig. 10 shows the details of the form for one column. The sections parallel to the side of the pier were made 3 ft. wide and braced by 3x6-in. vertical studs, and by horizontal girts running the full length of the pier. The sections for the column sides perpendicular to the face of the pier were made of the exact width of the column and fitted in between the side sections. The sheeting for these sections was nailed to 3x6-in. posts, which were offset at the bottom from shorter posts supported on the footing girder. The top posts were beveled at the top for the 3-in. offset to the top girder, and also afforded support for the arch centers.

The arch centers were made up of solid semicircles of 2-in. lumber. The 1x2-in. lagging was made just long enough to fit between the forms for the faces of the pier. The reverse curves at the ends of the piers were cut from 2x12-in. boards and were nailed to the inside of the side forms to support 1 × 2-in. lagging. Cleats were nailed across the tops of the pier forms to support the reinforcing bars in the top beam and to keep the forms from spreading.

All steel was wired into place before the concrete was poured. A loose board was left at the bottom of each column to make it possible to inspect and clean out the form before placing concrete. To remove the forms it was only necessary to take off the side girts and the centering for the reverse curve cantilevers, after which the sections could be peeled from the face of the pier.

Forms for the abutments were of the Bridge & Building Department's standard type for such work, consisting of 2x8-in. form lumber supported by 3x6-in. posts spaced about 24 ins., which in turn were braced by double 3x6-in. girts. The forms were tied across by form bolts and No. 10 wire.

Two alternative methods for the concreting plant were considered: (1) a mixer set up on the ground to handle material dumped at the site, and (2) a concreting train. The first method proposed would make construction less dependent on train service and would obstruct the track only during the unloading of material. Its disadvantages, however, were numerous; the equipment could not be used continuously, the concrete would have to be raised with a derrick or wheeled into position, and at many points the right-of-way was hardly wide enough to provide sufficient space for the accommodation of the plant and material.

The method of concreting direct from trains was adopted. To permit this, both facing and trailing switches were put at convenient intervals. With this arrangement either track could be used over the various crossings and all trains were operated single track through the block while the mixer was in use. A pilot and switchman were used to handle trains through the block, on account of the fact that there was no dispatching system. There were three concreting trains operated. The mixers were mounted on flat cars in such a position that the discharge just cleared the end of the car. The cars of material averaged three cars of stone, two cars of sand, and one car of cement, following the mixer in the order named. An old locomotive boiler was mounted and hauled in the rear of the train during winter months to furnish steam for heating concreting materials.

Both chutes and wheelbarrows were used in depositing the concrete. The use of chutes was

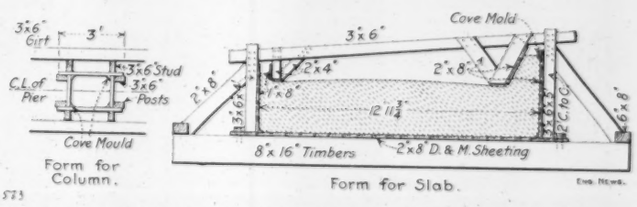


FIG. 10. FORMS FOR CONCRETE COLUMNS AND SLABS.

found to be the least satisfactory for piers because it required the train to be spotted at each pier in turn. The use of wheelbarrows made it possible to concrete all of them at the same time, thus permitting the use of a larger crew and doing away with considerable switching and delay.

CONSTRUCTION OF SLABS.—The slabs were molded in the Howard Ave. yard at the south end of the track elevation, an average of one mile from their place of erection. The ground on the site was first leveled and second-hand 12 × 12-in. or 8 × 16-in. sills were laid and driven to a uniform bearing with a 65-lb. sheet pile

pounder. A floor of 2 × 8-in. planking was laid on the sills, and the whole carefully leveled with an instrument. The slabs were cast to bring the direction of the span parallel to the joints in the floor.

The forms for the face of the slab parapet were made up of 3 × 6-in. posts 5 ft. high and spaced 24 ins. apart, sheeted with 2 × 8 in. planking, which extended within 12 ins. of the top of the posts. The forms for the ends and backs were made of 3 × 6 × 48-in. posts spaced 24 ins. and

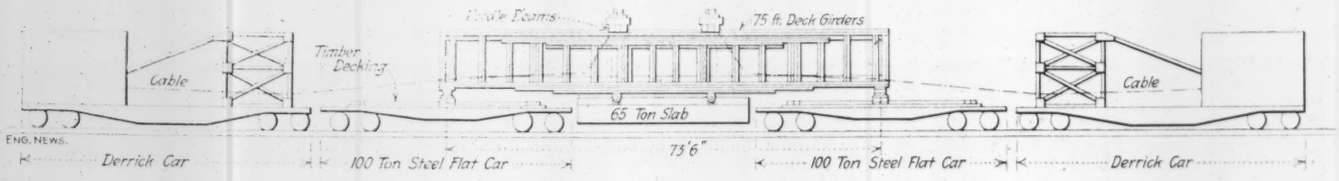


FIG. 11. ELEVATION OF TRAIN USED IN TRANSPORTING AND ERECTING THE REINFORCED-CONCRETE SLAB SPANS OF THE EVANSTON TRACK ELEVATION BRIDGES; C., M. & ST. P. RY.

sheeted with 1-in. boards. The side forms were braced to 6 × 8-in. timbers spiked to the projecting end of the sills. The sides were made long enough for the longest slab, but were used for the shorter slabs as well; each side and end was built as a complete section and moved from place to place on a push car. It was found possible to use each section about 12 times, after which the sheeting was renewed. The old lumber was used for backs of walls and abutments and for sheet piling.

Pairs of posts in the side forms were directly opposite, and a 2 × 8-in. or 3 × 6-in. plank was spiked to their sides above the sheeting. These timbers stiffened the entire form, afforded support for the reinforcing bars, carried the forms for the back of the parapet, and sustained runways for the wheelbarrows. Fig. 10 shows these details. Blanks made up of 1 × 8-in. lumber and 1 × 4-in. cleats were nailed to the inside of the parapet form to produce the recessed panels in the face of the finished slab.

The reinforcing bars and stirrups for the track slabs were cut to the proper length and bent to the required shapes at the yard. They were hauled to the forms on a push car and wired into place. The lower longitudinal bars were first laid on wooden blocks at the required distance from the top of the floor, cross bars were next placed and wired to the longitudinal bars to act as spacers, and finally U-stirrups were hooked under the longitudinal bars at the bottom and supported by wire from the top cross pieces of the form. After all bars had been hung from the form in this manner, the small blocks were removed and the concrete was poured.

The concrete mixer discharged into a hopper with a gate at the lower end, and each workman loaded his own barrow by lifting this gate. The mixer was spotted each day in the most convenient location relative to the slabs to be concreted in that day's work. When the form had been filled to within about 4 ins. of the top, the supporting wires were cut and pushed down into the concrete in order that the slabs might be finished to the required surface.

ERECTION OF SLABS.—The problems involved in the erection of the slabs were the transportation from the seasoning yard to the respective bridge sites, and the placing of them in their final position, with the least possible interference with passenger traffic. The first idea was to transport the slabs on flat cars and place them with a derrick car or wrecking crane. The company had a number of 100-ton wrecking cranes and a number of 30-ton to 50-ton derrick cars available, and it was found that the sidewalk slabs could be handled readily in this way.*

The roadway slabs, however, averaged about 65 tons each, and needed special consideration. The use of a 100-ton wrecking crane was considered first. The slabs were to be handled by means of a triangular toggle frame attached to the stirrups embedded in the concrete. The frame consists of a channel strut and two pairs of eyebars which extend from the ends of the strut to a pin over the middle of the slab. This device is used by the Bridge and Building Department in the erection of concrete trestle slabs. The use of the device requires a reach on the part of the crane equal to at least half the length of the slab, and this reach could not be obtained in this case without a considerable outhaul and alteration in the body of the car.

The next scheme involved the use of a derrick car at each end of the slab. The cars were to be spotted at each side of the span and the slab was to be brought up on the second track and lifted from the flat car into place. This plan would interfere with traffic on both tracks to an undesirable extent and would require an excessive side lift or reach, with the accompanying necessity for blocking the outriggers and guying the towers.

A scheme for bringing the slab to the bridge site between derrick cars and on the same track was suggested as an alternative and found to be better in some respects, but far from satisfactory. At this junction an erection device was suggested by Mr. C. F. Loweth which eliminated all the uncertainties accompanying derrick car erection.

This device is shown in Fig. 11 and consists of a 75-ft. plate-girder span (taken from stock and temporarily available), mounted on two 100-ton steel flat cars. The cars are spaced to permit the slab to hang between them when attached to the girders, and are provided with a special timber deck of 8 × 16-in. timbers securely cross braced and bolted to the car body. Transverse to this decking are two 12 × 12-in. bolsters carrying a bearing plate upon which the

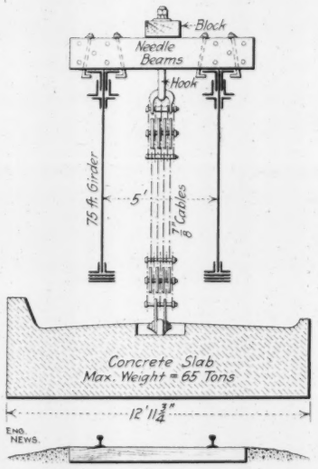


Fig. 12. Arrangement of Tackle for Suspending and Placing Concrete Slabs.

bearing plate and timber bolster of the girders is placed. A king pin was passed through both plates and bolsters and the plates were kept well greased to permit of turning. The train pull was transmitted from the girders to the cars by means of a special lower lateral system which provided a pin plate to receive the king pin.

Fig. 12 is a cross section of the girders and shows the method of supporting the slabs. Two pairs of 8 × 16-in. needle beams spaced 8 ins. apart, and carrying a wooden block with hook, spanned the girders. Each end of the concrete slab was suspended from a set of these beams by tackle made up of two four-sheave blocks and nine parts of ⅞-in. wire cable. Two derrick cars were coupled to the train, one at each end, and the lines supporting the two ends of the slab were controlled by the respective derrick car enginemen.

The procedure in placing the slab with this device was as follows: The slab was jacked up and placed on girder carriages mounted on rails. After the erecting train had been properly placed, the girder carriage track was extended across the main track, and the slabs were rolled underneath the girders, connected, lifted, and carried to the bridge site. The train was spotted in a position which would bring the slab directly above its final bearings, the track was removed, the falsework was torn out, and the bridge seats were prepared with a stiff cement mortar. When all was in readiness the slab was carefully lowered into place. By making the mortar of the right consistency and thickness, and by raising and lowering the slab a few times, it was found possible to bring the thickness of the bed to the required dimension and to line up the adjacent slabs in a very satisfactory manner. Fig. 13 shows the placing of the northwest roadway slab at Washington St.

Retaining Walls.

The right of way through Evanston varies in width from about 40 ft. to about 115 ft. The two tracks were elevated to an average height of about 17 ft. above the surface, and provision was made for the future addition of a third track. With these conditions, it would have been necessary to build a retaining wall along at least one side of the right of way for practically the full length of the track elevation, if it had not been for the fact that the right of way adjoined that of the C. & N. W. Ry. for a large part of the distance. The two railways entered into an agreement by which the space between the shoulders of their respective embankments was to be filled to the level of the tracks, and the cost of about 8,000 ft. of full height retaining wall saved to each company.

DESIGN.—There is about 4,500 ft. of retaining wall, the walls varying in height (above the ground surface) from 3 ft. to the full height of the embankment. With a few exceptions, the walls were of the ordinary plain concrete gravity section similar to the abutments, on account of conditions beyond the control of the designer. Rankine's theory of earth pressure was used in designing for the lateral forces. The effect of the live load surcharge was calculated on an assumption of vertical spread through the embankment. The maximum toe pressure was limited to 1¾ tons per sq. ft. As a rule the walls were constructed in alternate sections approximately 25 ft. long, the construction joints being marked with a V groove. The appearance is improved wherever possible by the addition of a coping and rectangular recessed panels. In cases where it is desired to provide for a future increase in height which might be made necessary by the shifting or addition of tracks, the design of the footings was modified and a heavy step is added to the back of the neat work in order that any future extension will require a minimum of excavation and give the greatest stability to the final wall.

There were a number of inclined teamways required by the Chicago & Northwestern Ry. adjoining the right-of-way and at these points it was necessary to build retaining walls. These teamways are on a 5% grade, making a total length of about 265 ft. of wall in each case. As the C., M. & St. P. Ry. found it necessary to

*Some derrick cars of the C., M. & St. P. Ry. were described in our issue of June 24, 1909.—Ed.

place its embankment before the fill for the teamway was made, a wall founded on the natural ground and capable of sustaining the embankment without front support, was required. With the teamway in place the difference of the elevation of the earth on the two sides, and therefore the overturning moment, for that part

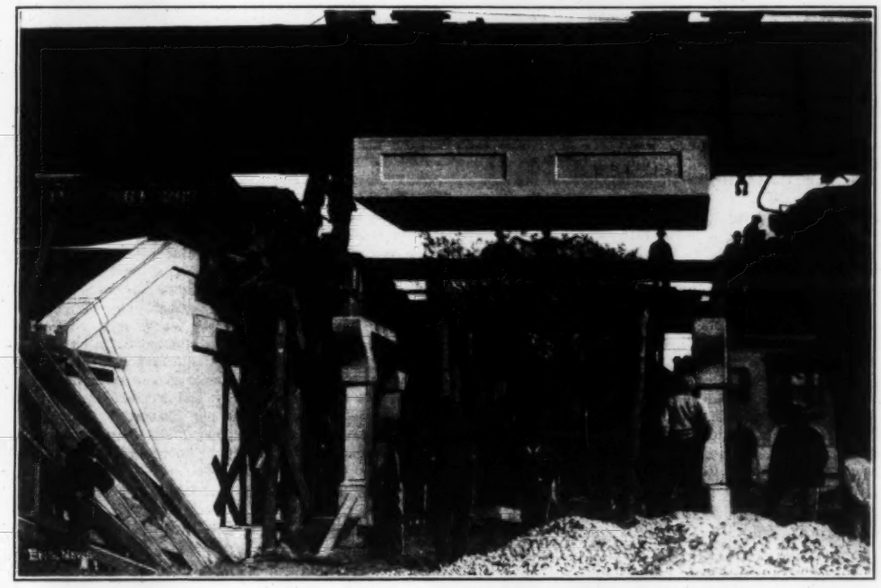


FIG. 13. PLACING A REINFORCED-CONCRETE SLAB SPAN OF THE WASHINGTON ST. SUBWAY.

of the retaining wall at the upper end would be small, and the lower part of the wall would be buried and useless.

On account of this fact the design shown by Figs. 14 and 15 was adopted as the most economical under the circumstances. This provides a full height solid gravity retaining wall to a point 90 ft. from the summit of the teamway. The wall beyond this point consists of a curb coming 3 ft. below the final surface of the teamway and supported on buttresses. The curb wall was reinforced as a beam to carry its weight between piers and was made of a section sufficient to give it stability in itself. The buttresses or piers and their footings were proportioned to sustain the entire structure when under the action of the back-fill before the teamway was in place without exceeding the allowable pressure on the foundations. The cross section, Fig. 15, taken between the two piers nearest the upper end of the teamway, shows the details of the curb wall and buttress, the relative elevations of the track and teamway and the position of the slope line before the teamway was in place.

monotony of the long stretch of concrete surface in a satisfactory manner. The coping is continuous. The panels are 9 ft. long by 3 ft. high, and 3 ft. 6 ins. apart.

CONSTRUCTION.—The form work for retaining walls was of the railway's standard type as described in connection with the abutments. There were several cases, however, where the location of the tracks made it impossible to support the forms by the usual outside braces. In these cases the rather unusual expedient was adopted of tying the side forms to bolts embedded near the opposite edge of the concrete footings.

The concrete for retaining walls at some distance from the track was placed by means of a stiff-leg derrick mounted on a flat car of the concreting train and carrying a concrete bucket (Fig. 17) designed by the Bridge and Building Department for this special purpose. A sliding discharge gate at the small end is controlled by a handle and a system of levers. The position of the levers and the gate while concrete is being discharged is shown by dotted lines. This bucket proved especially convenient in discharging into narrow openings, and was easily controlled.

Stations.

There are four passenger stations on the track elevation, as shown in Fig. 1. They are about ½-mile apart. The narrow right-of-way and the lack of space at the level of the elevated tracks made it necessary to place the station buildings at the street level. The station design will be described more fully in a later issue.

Platforms from 225 to 240 ft. long, sufficient to provide for six-car trains, were required. They were to be located on tangents, and the stairways leading to them placed as near as possible to the middle of the platform.

For the location of the platforms two alternative plans were considered; island platforms between the tracks, and platforms outside of the tracks. The advantages of the island platform were: (1) smaller floor area required than for two independent platforms, (2) less difficulty in providing shelter, (3) no hand-railings required, and (4) shorter subways and fewer stairways needed. They presented several distinct disadvantages; they required the spreading of the tracks (with four reverse curves and an additional width of embankment), and they permitted passengers to change to cars running in an opposite direction without paying for the return trip. Platforms located outside of the tracks had none of these disadvantages, and were adopted.

Miscellaneous Work.

PAVING.—The grading and paving of the subways and their approaches were done by contract in accordance with the specifications, under the supervision of the Bridge and Building Department. The streets were paved with brick. The subgrade was prepared by removing all rubbish, excavating and filling where necessary, and compacting by a roller. Upon a 6-in. layer of 1:3:7 limestone concrete was laid a 2-in. cushion of sand for the brick. The brick was brought to the face of the concrete curbs, a combination concrete gutter not being considered desirable. The curbs were 6 × 36 ins., and were placed around the center piers as well as on both side of the street. They were rounded to a 6-ft. radius at street intersections and to a 3-ft. radius at alleys. The sidewalks were made up of a 3½-in. layer of concrete with a ½-in. finishing coat of 1 to 1 mortar; the whole was laid on a 7-in. layer of sand. Expansion joints were provided at 40-ft. intervals.

FILLING.—The actual track raising was begun in the spring of 1909 and was carried on by the engineering department. To facilitate the handling of material a temporary yard was built at Howard Ave., and the engines on the work usually remained in this yard at night, thus eliminating delays due to late arrival of motive power. Side-dump cars were used and all material was unloaded by hand. About 300,000 cu. yds. of material was used for the entire work. It consisted of sand and gravel hauled from the Fox Lake region.

The scheme of raising tracks was according to the usual method. One track at a time was thrown out of service, cars were emptied, the material leveled, and the tracks were raised about 6 ins. to 8 ins., ready for the next load of filling. When the difference in elevation of the two tracks became about 2 or 3 ft., the traffic was shifted and the low track raised.

Owing to the narrow right-of-way the problem of raising the tracks at some places was quite complicated, especially where space had to be left for walls which could not be completed before the elevation was begun. At such points a system of bulwarks was employed. The work over Main St. is typical. Retaining walls were required on both sides of the right-of-way north of Main St. and on the west side south of Main

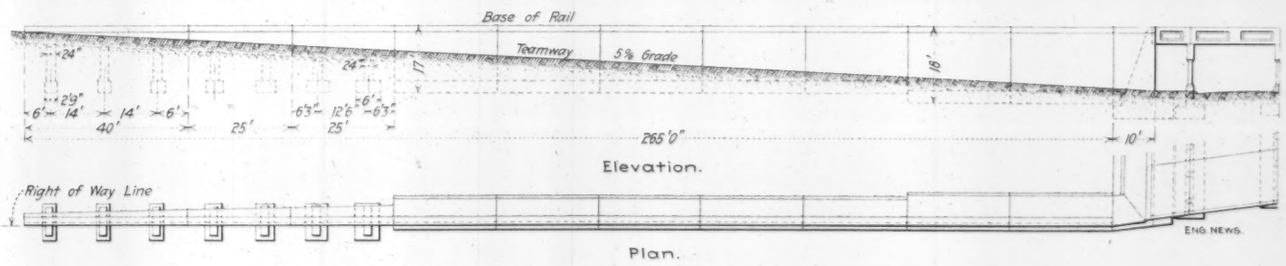


FIG. 14. REINFORCED-CONCRETE RETAINING WALL FOR INCLINED TEAMWAY OR DRIVEWAY.

The ordinance required a concrete wall or fence 7 ft. high for a distance of about 1,560 ft. along Chicago Ave., where the C., M. & St. P. Ry. was permitted to extend its right-of-way to the curb line. This wall is of variable section depending on the grade and the position of the nearest track. From Madison St. south there are two team tracks parallel to Chicago Ave., rising on a grade of 0.5%. Fig. 16 is a cross section on the wall at this location, showing the method of providing for the 7-ft. height required by the ordinance. The coping and paneling break the

St. The tracks were first raised about 4 ft. over the crossing and temporary bridges put in to keep the street open for traffic. North of the crossing the west track was raised as high as possible without interfering with the operation of the east track. Then the east track was thrown out of service in its turn and elevated, and a falsework bridge was put in across the street.

Piles were driven on both sides of the track north of the bridge for a distance required to prevent the slopes of the embankment from blocking the west track and northeast wall lo-

cation. These side piles were from 22 to 30 ft. long and had from 10 to 18 ft. penetration. They were driven about 7 ft. c. to c. and old ties were thrown in behind them to retain the fill. It was found that after a time they began to spread and consequently were tied together by a number of strands of No. 10 wire running through the embankment just below the track.

DRAINAGE.—The backs of abutments and retaining walls were not waterproofed. The fill was drained with 6-in. tile laid along the back of

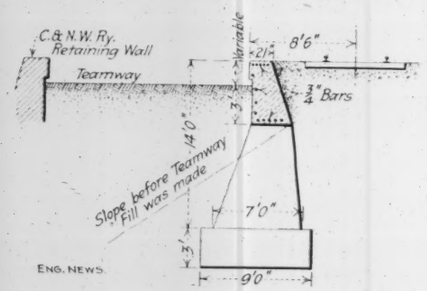


Fig. 15. Cross Section of Retaining Wall for Teamway.

the walls, one drain served for retaining walls, but two lines were laid behind abutments, one near the bottom and one near the top. Tile pipe laid between the tracks drained the subgrade. A combination manhole and catch-basin with about 3 ft. interior diameter was placed behind each abutment. All drains were carried into the nearest catch-basin, and the catch-basin in turn discharged into the city sewers through a 9-in. pipe. The subways are drained by suitable inlets which were in all cases located at some distance from the street intersections in order that the depth of gutter and the step at the sidewalk crossings might be as small as possible. The gutter grates were of the "Duplex" type. A catch-basin was located at each inlet and one manhole in each subway.

The design and construction of the subway bridges, retaining walls, concrete work connected with the stations, station buildings and platforms, as well as the street paving and drainage for the entire track elevation work, were executed by the Bridge and Building Department of the Chicago, Milwaukee & St. Paul Ry., under the direction of Mr. C. F. Loweth, M. Am. Soc. C. E., Engineer and Superintendent. The filling and track work were done by the Engineering Department. With the exception of a few minor

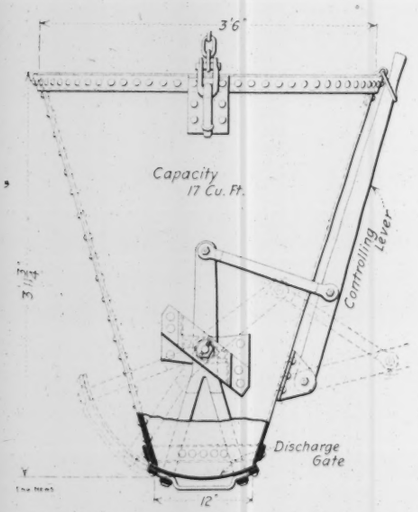


Fig. 17. Dumping Bucket for Delivering Concrete into the Forms, C., M. & St. P. Ry.

contracts, all of the construction work was done by the Bridge and Building Department's forces. The construction and design, respectively, were, in a general way, in charge of L. D. Hadwen and J. H. Prior; and were directly in charge of R. J. Middleton and of E. O. Greifenhagen, the latter being the author of this article.

Relation of Typhoid Fever and Water Supplies in Illinois.*

By EDWARD BARTOW.†

The typhoid fever death rate of the city of Chicago is lower than that of the lake cities of northern Indiana. This is evidently due to the superior character of the water supply of Chicago. All of these cities obtain their water supply from Lake Michigan, but the water-works intakes of the Indiana cities are near the shore and the water is shown by the Indiana State Board of Health to be seriously affected by the Calumet River through which the untreated sewage from a population of 500,000 people is emptied into the lake. The water supply of Chicago has been greatly improved by the extension of the intakes and by the diversion of the sewage through the drainage canal. Meanwhile the typhoid death rate of Chicago has fallen from 173 per 100,000 in 1891 to 15.6 per 100,000 in 1908.

A further reduction for Chicago seems possible, because water supplies have a death rate of only 7 or 8 per 100,000. What is possible in the cities of Vienna and Munich, with mountain-top supplies, Frankfort and Dresden, with artesian supplies in unquestioned soils; Zurich, Hamburg, Rotterdam and London, with properly filtered water, should also be possible in Chicago. The city of Rockford, Ill., where the drinking water is obtained from artesian wells of unquestioned purity, has a typhoid fever death rate of only 7 or 8 per 100,000. It therefore seemed that it would be interesting to determine the distribution of the typhoid fever throughout Illinois and thus learn in what parts of the state the greatest effort should be made to eliminate typhoid fever and to learn also whether the health of Chicago with respect to typhoid fever is more influenced

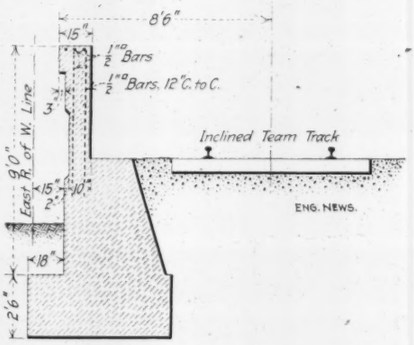


Fig. 16. Concrete Retaining Wall and Parapet.

by the typhoid fever throughout the state, or whether the health of the rest of the state is influenced by the typhoid fever in Chicago.

When the study of this subject was begun the only published statistics were those for 1907, given in the bulletin of the State Board of Health. The typhoid fever death rate per 100,000 was calculated from the data there given. The unpublished statistics of the State Board of Health were placed at our disposal through the courtesy of the Secretary, Dr. J. A. Egan and the Registrar of Vital Statistics, Mr. William J. Hoyt. From these statistics the typhoid fever death rates for the years 1904-5-6 and 8 were calculated. In making the calculations the population for each year, as estimated by Mr. Hoyt, was used.

A study of the statistics shows that it is not advisable to draw definite conclusions from the death rate during any one year. In Putnam Co., for example, the death rate was 75 per 100,000 in 1904. There were no deaths in any other year. Putnam Co. is a small county so that a typhoid fever death rate of 75 per 100,000 was obtained from three deaths in a population of 4,000. The average for five years was 15. A high death rate in any one year may be due to epidemic conditions. For example, an epidemic at Streator, in 1907, due to an infected water supply, raised the rate of La Salle Co. for that year to 30 per 100,000. In the other four years the rate was so low that the general average was 16.

The largest typhoid fever death rate is shown to have been in the southern part of the state. Only one of the 51 southern counties had an average death rate of less than 10 per 100,000 for the five years. This county (Douglas) is on the line between the two sections and as will be shown later is in an area of low typhoid fever. Only two other counties (Scott and Macoupin) have a rate below 15. That this average is not accidental and due to epidemics in any one year is shown by the fact that in only two counties was there a rate below 10 in three of the five years. In only three more was there a rate below 10 in two of the five years and in only 11 counties did the rate go below 10 in any one of the five years. In the 51 northern counties, on the other hand, there are 13 with an average rate below 10, and 10 more with an average rate below 15 per 100,000. Only 12 counties did not have in one or more years a death rate below 10 per 100,000.

In the southern half there are eight counties with an average death rate above 40 per 100,000 and 12 more with an average death rate above 30, whereas in the northern part of the state there is only one with an average rate above 40 (Cass), and this county will be shown later to be in an area of high typhoid fever; there is only one other having a rate above 30. The figures show that 31 of the 51 southern counties had an average death rate above 40 in one or more years, 14 of these counties had a rate of more than 40 in two or more years, and four of these had a death rate above 40 in three or four years and two in four years. Of the northern counties only five had a typhoid death rate above 40 in one year or more and only two counties had a rate above 40 in two years.

The studies have shown that the typhoid fever death rate is dependent to a considerable extent on the character of the water supply. In that part of the state north of a line drawn from Quincy to Lake Michigan, the greater number of the municipal water supplies are obtained from deep wells which enter rock and obtain water which, from a sanitary standpoint, is of unquestioned purity. In this section there are only three counties with a death rate above 25 and three more with a rate above 20 [between 20 and 25] and there are 10 with a death rate below 10 per 100,000.

In the east central portion of the state we find an area of glacial drift 100 ft. or more in depth. In part of this area the water supplies are obtained from deep wells which enter rock, but over half of the area has very few wells of this character because of the large amount of mineral matter in the water from the deep rock wells. The municipal water supplies in this section are obtained from deep wells which do not enter rock but which furnish a water supply of unquestioned purity from a sanitary standpoint. The low typhoid fever death rate in this section is due, therefore, to the satisfactory water supply obtained from these deep-drift wells. There are no counties located entirely within this area in which the typhoid fever death rate exceeds 20 per 100,000. Not only can satisfactory municipal water supplies be obtained from deep wells in drift, but many farms and private houses are also supplied from such wells.

It is interesting to note that the one county of the northern 51 counties which has a typhoid fever rate of more than 40 is located outside of the deep-drift area, and that the one county in the southern counties having a typhoid fever rate lower than ten is located within the deep-drift area.

In the southern portion of the state it is impossible to use the water from the deep-rock wells for municipal water supplies because of the large amount of mineral matter which they carry. The drift is not deep enough to yield a sufficient supply of water for cities. The municipal supplies, therefore, must necessarily be taken from streams or reservoirs and the private supplies must be drawn from shallow wells, often of doubtful character. The municipal water supplies are as a rule taken from streams or reservoirs without filtration. In fact only 16 of the 60 water supplies obtained from streams, lakes or ponds within the state have filtered water and only a few of the supplies in the southern portion of the state are filtered. It is claimed by the authorities in some of these towns that the water is used only for sprinkling, fire protection or for manufacturing purposes, but it is a difficult matter to prevent the use of such water for drinking purposes and it would be far better to furnish a filtered water than to allow the residents in the cities and villages to rely on individual wells for their drinking water.

It seems very probable that the high typhoid fever rate in the southern part of the state is due to a considerable extent to the lack of satisfactory general water supplies. Several communities are already considering the introduction of filtered water and it is hoped that a better report of the typhoid fever conditions in the southern part of the state may be given in the near future.

It is interesting to compare Macon and Sangamon counties. These are in the same latitude and contain large cities, Decatur and Springfield. The typhoid fever death rate of Macon Co. is 14 per 100,000, while that of Sangamon is 37. This is undoubtedly due to the fact that Macon Co. is within the deep-drift area and the water supplies for farms and private individuals can be obtained from deep-drift wells, whereas Sangamon Co. is outside of the deep-drift area and the farms must rely on the shallow wells for drinking water. Then, too, the city water supply of Decatur, in Mason Co., is filtered, whereas the water supply of Springfield, in Sangamon Co., is sometimes augmented by unfiltered water from the Sangamon River.

The typhoid fever rate of Chicago does not seem to be materially increased by infection from the neighboring counties. There are, in fact, no counties within 100 miles of Chicago which have a typhoid fever rate materially higher than Chicago itself.

*Abstract of a paper presented at the annual meeting of the Illinois Society of Engineers and Surveyors at Cairo, Ill., Jan. 26, 28.

†Director of the State Water Survey, Urbana, Ill.

The Type Characteristic of Impulse Wheels and Its Use in Design.

By S. J. ZOWSKI.*

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A previous article by the author, entitled "A Comparison of American High-Speed Runners for Water Turbines,"† gave the method of deriving a characteristic called the Type Characteristic, by means of which a convenient classification and comparison of existing runners and runner types is obtained. In a second article, entitled "A Rational Method of Determining the Principal Dimensions of Water-Turbine Runners,"‡ the convenience of using the Type Characteristic for computing *new* runners was demonstrated. Both articles, however, dealt with the radial inward-flow turbine only. But as the Type Characteristic renders equally good service with all other turbine classes, it is proposed in this article to investigate the impulse wheel in a similar way.

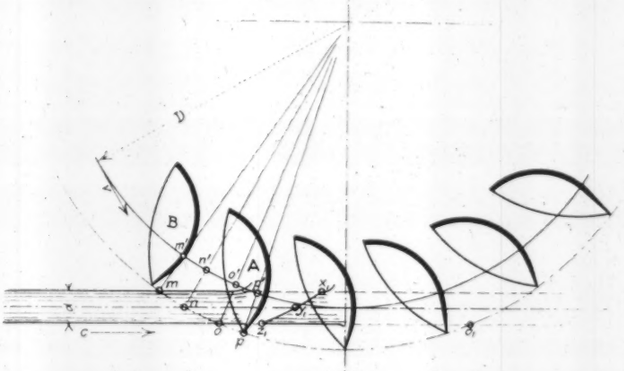

Fig. 1.

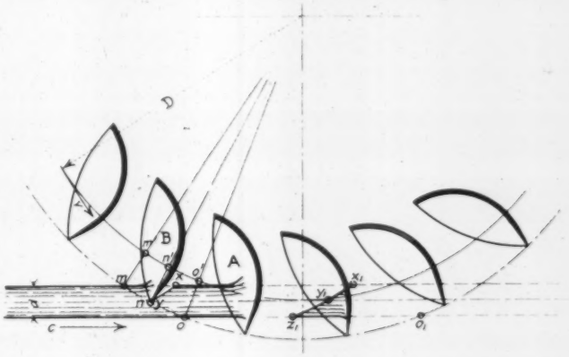

Fig. 2.

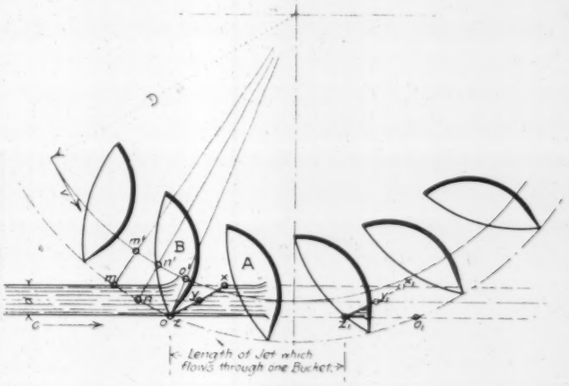

Fig. 3.

FIGS. 1-3. RELATION OF BUCKET AND JET IN THREE DIFFERENT POSITIONS.

The following notation will be used:

d = the actual diameter of the jet.§ In this country only circular nozzles are used, therefore square jets will not be considered at all in this article, although such jets would not change the theory materially.

D = the nominal wheel diameter, i. e., the diameter of the circle tangent to the center line of the jet, which circle might appropriately be called the "impulse circle." Some engineers call this circle the "Pelton circle," in recognition of Mr. Pelton's contributions to the development of the impulse wheel.

c = the velocity of the jet..

v = the peripheral velocity of the wheel, measured on the impulse circle.

H = the net head acting in the nozzle.

H-P = the power of the wheel, in horsepowers.

N = the rotative speed of the wheel, in revolutions per minute.

Unless specified otherwise, the foot and the second are the units.

Derivation of Type Characteristic.

The jet velocity c may be expressed in terms of the head as follows:

$$c = f_c \sqrt{2 g H} \qquad (1)$$

For nozzles of good design and workmanship, the velocity coefficient f_c may be taken as 0.97. The discharge of the nozzle is

$$Q = \frac{\pi d^2}{4} f_c \sqrt{2 g H} = 6.3 f_c d^2 \sqrt{H} \qquad (2)$$

The power developed by Q and H is

$$H\text{-}P = \frac{62.42 Q H}{550} e = \frac{Q H e}{8.8}$$

where e is the wheel efficiency.

By substitution we obtain:

$$H\text{-}P = 0.716 e f_c d^2 H \sqrt{H}$$

Substituting unity for H gives the power at head of one foot, or the specific power:

$$H\text{-}P_1 = 0.716 e f_c d^2 = K_P d^2 \qquad (3)$$

where $$K_P = 0.716 e f_c \qquad (4)$$

In determining the principal turbine dimensions, the wheel efficiency is generally assumed as 80%. Therefore we may substitute 0.8 for e, which with 0.97 for f_c gives $K_P = 0.5565$. Solving eq. (3) with this value, we obtain a convenient formula for figuring the required jet diameter.

$$\left.\begin{array}{l} \text{In feet} \quad d = \sqrt{\dfrac{1}{K_P}} \sqrt{H\text{-}P_1} = 1.34 \sqrt{H\text{-}P_1} \\ \text{or in inches,} \quad d = 16.1 \sqrt{H\text{-}P_1} \end{array}\right\} \qquad (5)$$

The peripheral velocity of the wheel, measured on the impulse circle, is

$$v = f_v \sqrt{2 g H} \qquad (6)$$

For polished or well-finished buckets the coefficient may be taken as $0.485 f_c$, which, with $f_c = 0.97$ equals 0.47.* Since the rotative speed of the wheel, N, is equal to $60\ v/\pi D$, we obtain by substituting the value of v from eq. (6),

$$N = 153.17 f_v \frac{1}{D} \sqrt{H}$$

Putting $H = 1$ in this formula we find the specific speed (speed at one-foot head) to be

$$N_1 = 153.17 f_v \frac{1}{D} = K_N \frac{1}{D} \qquad (7)$$

where $$K_N = 153.17 f_v \qquad (8)$$

For $f_v = 0.47$, $K_N = 72$.†

Using this value in eq. (7), we obtain a convenient formula for computing the required wheel diameter:

$$D = \frac{K_N}{N_1} = \frac{72}{N_1} = \frac{72 \sqrt{H}}{N} \qquad (9)$$

The expression for the Type Characteristic is

$$K_t = \frac{N \sqrt{H\text{-}P}}{H \sqrt[4]{H}} = N_1 \sqrt{H\text{-}P_1} \qquad (10)$$

Substitute for N_1 and H-P_1 their values from eq. (3) and (7). This gives

$$K_t = K_N \sqrt{K_P} \frac{d}{D}$$

$$= 153.17 f_v \sqrt{0.716 e f_c} \frac{d}{D} \qquad (11)$$

With $f_v = 0.47$, $f_c = 0.97$ and $e = 0.80$ (or with $K_n = 72$ and $K_p = 0.5565$), we obtain for the type characteristic the simple formula

$$K_t = 53.67 \frac{d}{D} \qquad (12)$$

Thus the type characteristic of impulse wheels is a simple function of the ratio of jet and wheel diameter. Therefore, the determination of the limiting values of K_t for impulse wheels means the determination of the limits for the ratio d/D with which reasonable efficiency may be obtained.

Limiting Ratios of Jet Diameter to Wheel Diameter.

It is obvious that there will be a certain maximum value for this ratio, because, going for instance to the extreme, a wheel diameter equal to the jet diameter, or $d/D = 1$, would evidently be impossible to use. Therefore there will be a certain *maximum* value for K_t which cannot be exceeded by an impulse wheel using a single jet.

A *minimum* value for K_t does not exist, theoretically, as the ratio d/D could be decreased to any desired amount. In practice, of course, we would come to a limit also in this direction, on account of the limitation as to the size of a wheel. But actual problems would never bring us near this limit, as a wheel of given capacity would never be required to have so low a rotative speed (hence low K_t) as to require wheels of diameters too large to be built or operated successfully. We therefore do not need to consider the question of the minimum value for K_t at all.

The question of the maximum value for K_t, however, is of great importance for practical application, as this will determine the number of wheels or number of nozzles required for the given power and speed. To answer this question, we need, since K_t is a function of d/D, only to find the least wheel diameter that can be used satisfactorily in connection with a jet of given diameter.

The sketches, Figs. 1, 2 and 3, bring out the chief conditions involved. As bucket B progresses from the position shown in Fig. 1, the jet

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†Engineering News, Jan. 28, 1909, pp. 99-102.

‡Engineering News, Jan. 6, 1910.

§This is not the nozzle diameter, but the actual diameter of the jet at the contraction, if there is one, or in any case at the minimum section.

*The value of $f_v\sqrt{2g} = 3.77$ corresponds to the speed constant $K_v = 4.588$ to 7.006 for radial inward-flow turbines.

†The corresponding value of K_n for radial inward-flow turbines is 87 to 134.

will be split in two parts, one feeding bucket B, the other proceeding with the jet velocity c in its initial direction. When bucket B reaches the position shown in Fig. 3, the water particle which was at m when bucket B separated it from the main jet will have moved to x. Similarly, the water particle which was at n when the bucket

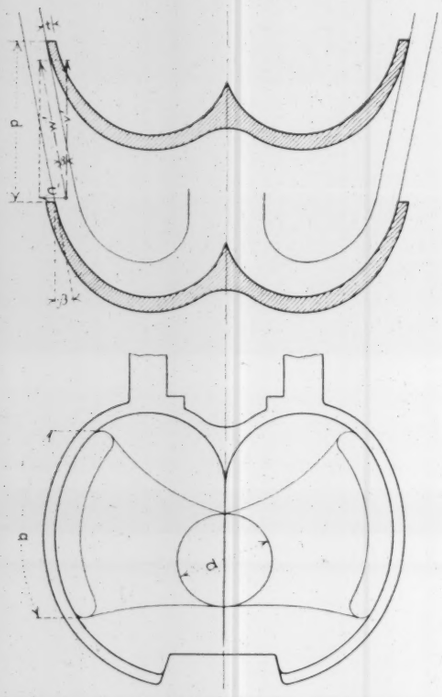


Fig. 4. Path of Jet Discharging from Bucket.

separated it from the main jet (Fig. 2) will have moved to y (Fig. 3). These distances are

$$m\,x = m'\,o' \times \frac{c}{v} = m'\,o' \frac{f_c}{f_v} = \frac{m'\,o'}{0.485}$$

$$n\,y = n'\,o' \times \frac{c}{v} = n'\,o' \frac{f_c}{f_v} = \frac{n'\,o'}{0.485}$$

The curve xyz, Fig. 3, shows thus the end of the jet which has been cut off from the main jet, in its correct instantaneous position at the time when the entrance edge of bucket B is at o. As the wheel moves farther, the separated jet will move, too; when the bucket B reaches, for instance, the position of bucket A in Fig. 1, the curve xyz (Fig. 3) will be moved to $x_1\,y_1\,z_1$ (Fig. 1). These distances are,

$$m\,x_1 = m'\,p' \times \frac{c}{v} = m'\,p' \frac{f_c}{f_v} = \frac{m'\,p'}{0.485}$$

$$n\,y_1 = n'\,p' \times \frac{c}{v} = n'\,p' \frac{f_c}{f_v} = \frac{n'\,p'}{0.485}$$

$$o\,z_1 = o'\,p' \times \frac{c}{v} = o'\,p' \frac{f_c}{f_v} = \frac{o'\,p'}{0.485}$$

It is apparent that, in order to utilize the entire energy contained in the jet, no particle must slip through, without giving up its energy to the buckets. Therefore, the wheel and buckets must be designed so that the last particle of the jet separated by bucket B from the main jet, namely particle z, will *reach* bucket A and will be *fully deflected* by bucket A before this bucket, or that point of the bucket at which the last particle should discharge, leaves the sphere of the jet.

While it is a simple matter to determine the position of the bucket A at the moment when the last particle reaches it, it is very difficult, if possible at all, to determine the position at which the last particle has just completed its flow through the bucket. A great deal of judgment must be used in this respect, and, therefore, special care is advised in all cases where only a short time is left for the bucket to remain in the sphere of the jet after the last particle has entered.

This time can be increased in two ways: (1) By decreasing the time necessary for the last particle to *reach* the bucket A. This is secured by decreasing the pitch of the buckets, thus shortening the sections of jet cut off by the buckets. (2) By increasing the total length of time during which each bucket remains in the sphere of the jet, or in other words, by increasing the length of the arc oo_1.

In decreasing the pitch or increasing the number of the buckets, however, we soon come to a limit. From Fig. 4, showing two consecutive buckets in section, it is apparent that the smaller the pitch, the larger the angle must be in order that the water may freely discharge from the bucket without hitting the following bucket. But with increasing β, the lateral component c' of the water velocity grows larger, and this means increased discharge loss $\frac{(c')^2}{2g}$; hence the wheel efficiency is decreased. Efficiency demands that we should make angle β as small and the pitch as large as possible. Allowing a certain discharge loss as the maximum, we cannot reduce the pitch beyond that which corresponds to this discharge loss. Furthermore, practical considerations will not permit using an excessive number of buckets. If, for instance, the buckets are bolted to the wheel disk, which is the general practice in this country, the flanges must have a certain width, thus giving a minimum pitch which may not even be as small as that resulting from the value of the discharge loss that we are willing to allow. In other words, decreasing the pitch of the buckets, for the sake of lengthening the time left for the bucket to remain in the sphere of the jet after the last particle has entered, can be carried only to a certain limit.

Beyond this limit the flow conditions of the last particle can be improved only by lengthening the arc oo_1. This we can secure by increasing the height of the arc, i. e., by making the buckets longer. But here again we are not able to go very far, as it is obvious that the buckets cannot be made excessively long in comparison with the wheel diameter. We come thus to a limit also in this direction, and if now the flow conditions are not satisfactory, the last but most effective means will have to be used, namely that of increasing the length of the arc by increasing the wheel diameter proper, or decreasing the value of K_t.

This, it is believed, shows clearly the nature of the impulse-wheel problem, when for a given size of jet the least possible wheel diameter, or the maximum value of K_t, is to be determined.

Maximum Type Characteristic.

In the summer of 1908 the writer had to deal with this problem quite extensively, when he was developing a type of buckets which were to be used as "standards" and which would reach the minimum value of K_t allowable for radial inward-flow turbines, with as few wheels or nozzles as possible. After all means to improve the flow conditions for the last particle, as described above, had been exhausted; that is to say, after the pitch had been reduced to a minimum and the length of the buckets had been increased to a maximum, the least wheel diameter with which a perfect reaction of the last particle could be obtained was about 10.5 times the jet diameter. With wheel diameter reduced to 9 times the jet diameter, about 2% to 3% of the jet would not react fully.

On account of the necessity of making several arbitrary assumptions in order to be able to find the position of the bucket at the time when the last particle of water has completed its flow through the bucket, the results involve some degree of uncertainty in the neighborhood of the critical point. Therefore, the values found by the writer must not be looked upon as being mathematically exact.

The question whether the wheel diameter should not be brought below $D = 10.5d$ or whether it should be allowed to go somewhat lower, say, to $D = 9d$, cannot be settled by a general rule, as efficiency is not always the only deciding factor. There will be many cases in practice where the advantages of a higher value of K_t, and consequently reduced number of wheels or nozzles necessary for the given power and speed, will justify a certain additional loss by imperfect reaction. A loss of 3% will often be allowable to secure these advantages. Therefore, let us establish as limiting values:

(1) $\frac{d}{D} = \frac{1}{10.5}$, making K_t about 5; for perfect reaction.

(2) $\frac{d}{D} = \frac{1}{9}$, making K_t about 6; when loss from imperfect reaction can be about 2% to 3%.

The writer does not advise trying to carry K_t higher than 6, as the loss due to imperfect reaction increases rapidly. It must be borne in mind, however, that even values of 5 or 6 can be obtained only by buckets especially adapted for such high values. These buckets must be considerably longer than standard Pelton or Doble buckets, for instance.

In these special buckets, which may appropriately be called high-speed buckets, the part X, Fig. 5, is particularly important. The smaller the wheel diameter the more inclined will be the bucket relatively to the jet at the moment when the last water particles enter, and consequently more water will be discharged at part X. This makes it necessary to design this part of the bucket with the same care as part Y, where the first and main part of the jet discharges; the bucket must be kept sufficiently deep at X and the angle β kept sufficiently small. Also another point must be mentioned in this connection: Because the increased length of the bucket makes the flow conditions at the entrance in the bucket less favorable, the practice of moving the entrance edge toward the center, as is done on all modern buckets of good design, becomes a necessity for high-speed buckets.

In the article "A Rational Method of Determining the Principal Dimensions of Water Turbine Runners," it was shown that the minimum value of K_t for radial inward-flow turbines is about 12. With favorable conditions, slightly smaller values can be reached, down to about 10. (The Allis-Chalmers Co., of Milwaukee has built a radial inward-flow turbine for the Palmer Mountain Tunnel and Power Co. for the following data: $H = 350$, $H\text{-}P = 650$, $N = 600$; these make $K_t = 10.2$.). If now the maximum value of K_t for impulse-wheels is 6, it is apparent that we can equal the minimum limit of radial inward-flow turbines by using four single-nozzle impulse-wheels, or a four-nozzle wheel; thus the entire field of requirements for water-turbines can be covered satisfactorily by these two turbine classes alone. The conditions in this direction have been improved recently by the development of two-stage radial inward-flow turbines, a few of which have been in successful operation in Europe. These two-stage turbines extend the

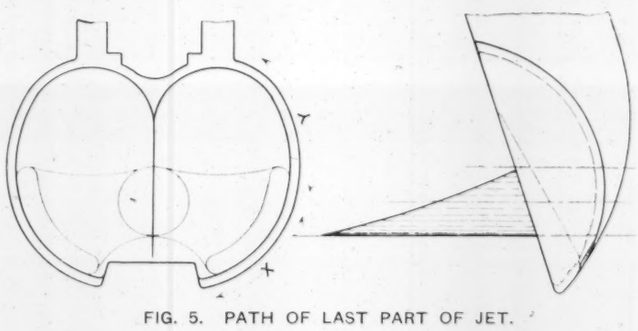


FIG. 5. PATH OF LAST PART OF JET.

ield of the radial inward-flow turbine in the neighborhood of the minimum limit.*

Summary.

If the value of K_t computed from the given power, head and rotative speed is smaller than 12, but larger than 6, a multiple impulse-wheel must be built.

If K_t is equal to 6, a single impulse-wheel can be built, but in this case an additional loss of 2% to 3%, due to imperfect reaction of some part of the jet, must be reckoned with.

If K_t is 5 or less, a single impulse-wheel can be used without any additional loss due to imperfect reaction. However, as long as K_t is larger than about 4.2, the design must be very careful, and the buckets must be increased in length as compared with the usual standard buckets.

Best conditions for the design prevail when K_t is between 2.5 and 3.5.

After the question of the number of wheels or nozzles has been decided upon, the jet diameter will be found from formula (5).

$$d \text{ (in inches)} = 16.1 \sqrt{H\text{-}P_1}$$

where $H\text{-}P_1$ is the power of one jet per foot of head, in horsepower. The wheel diameter will be found from eq. (12).

$$D = \frac{53.67\ d}{K_t}$$

which value must check with that given by eq (9):

$$D = \frac{72 \sqrt{H}}{N}$$

NUMERICAL EXAMPLE.—Given $H = 900$ ft.; $H\text{-}P = 7{,}500$ HP.; $N = 400$ r. p. m. Determine the arrangement and dimensions of the turbine.

$$H\text{-}P_1 = \frac{7500}{900 \sqrt{900}} = 0.2778$$

$$N_1 = \frac{400}{\sqrt{900}} = 13.333$$

$$K_t = 13.333 \sqrt{0.2778} = 7.035$$

This value is too small for a radial inward-flow turbine and too large for a single impulse-wheel. Choosing, therefore, one wheel with two nozzles, or better, two wheels with one nozzle each, K_t for each jet will be reduced to

$$K_t = \frac{7.035}{\sqrt{2}} = 4.97$$

which would require buckets of very careful design and somewhat elongated shape. On the other hand, if we decide to use four jets, i. e., either four wheels each with one nozzle, or two wheels each with two nozzles, then K_t per jet would be reduced to

$$K_t = \frac{7.035}{\sqrt{4}} = 3.5175$$

Both solutions are possible, and in deciding between them the advantages and disadvantages of each should be carefully considerd. The first solution will give us a smaller and cheaper unit, but lower efficiency, whereas the second solution will give us a considerably larger unit, which will cost more and require more space in the power-house, but which will have better efficiency.

*A two-stage turbine for H, $H\text{-}P$, N requires runners of

$$K_t = \frac{N \sqrt{0.5\ H\text{-}P}}{0.5\ H \sqrt[4]{0.5\ H}} = \sqrt[4]{8}\ \frac{N \sqrt{H\text{-}P}}{H \sqrt[4]{H}}$$

Thus, if a single-stage turbine has a runner of $K_t = 12$ the runners of a two-stage turbine for the same total power, head and speed would be of $K_t = \sqrt[4]{8} \times 12 = 20.184$. Or, if we consider 12 as the minimum value of K_t for radial inward-flow *runners*, we could, in using a two-stage turbine, reach by radial inward-flow *turbines* a type chara teristic as small as $\frac{12}{1.682}$ = about 7.2.

(1) The first solution will require a jet of diameter

$$d \text{ (in inches)} = 16.1 \sqrt{\frac{0.2778}{2}} = 6 \text{ ins.}$$

and a wheel of diameter

$$D \text{ (in inches)} = \frac{53.67 \times 6}{4.97} = 64.79 \text{ ins.}$$

which checks with

$$D \text{ (in feet)} = \frac{72 \sqrt{900}}{400} = 5.4 \text{ ft.} = 64.8 \text{ ins.}$$

(2) The second solution will require a jet of

$$d \text{ (in inches)} = 16.1 \sqrt{\frac{0.2778}{4}} = 4.24 \text{ ins.}$$

and a wheel of

$$D \text{ (in inches)} = \frac{53.67 \times 4.2432}{3.5175} = 64.8 \text{ ins.}$$

which checks with the value obtained before.

If other values for f_c, f_v and e seem to be more appropriate than 0.97, 0.47 and 0.80, respectively,

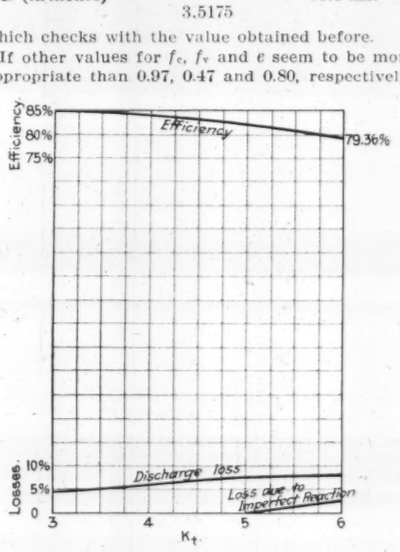


Fig. 6. Performance of Impulse Wheels: Variation of Losses and Efficiency with Type Characteristic.

the general formulas (3) and (7) should be used in computing d and D.

Discharge Loss.

At the end an interesting relation between the discharge loss, the angle β, the Type Characteristic, and the pitch or number of buckets shall be derived.

Assume that the bucket is in such a position that the center of the discharging water stream is on the impulse circle; then the peripheral velocity of this center v', is equal to the wheel velocity v.

$$v' = v = f_v \sqrt{2 g H} = 0.47 \sqrt{2 g H}$$

The discharge is, by Fig. 4,

$$Q = 2\ b\ w' (p \sin \beta - t) = \frac{\pi d^2}{4} f_c \sqrt{2 g H}$$

Also, $$w = \frac{v}{\cos \beta} = \frac{f_v \sqrt{2 g H}}{\cos \beta}$$

Substituting the last value in the preceding expression,

$$\frac{2 b f_v \sqrt{2 g H}}{\cos \beta} (p \sin \beta - t) = \frac{\pi d^2}{4} f_c \sqrt{2 g H}$$

Neglecting t as small compared with $p \sin \beta$, we get

$$\tan \beta = \frac{\pi d^2}{8\ b\ p} \frac{f_c}{f_v}$$

or, substituting for p its value $\pi D n$ in terms of the number of buckets n,

$$\tan \beta = \frac{d^2\ n\ f_c}{8\ b\ D\ f_v} = \frac{n}{8} \frac{d}{b} \frac{d}{D} \frac{f_c}{f_v} \qquad (13)$$

Since $\frac{d}{D} = \frac{K_t}{53.67}$, this becomes

$$\tan \beta = \frac{n\ K_t}{429.36} \frac{d}{b} \frac{f_c}{f_v}$$

In regard to the ratio of $\frac{d}{b}$, we possess no definite data, as no satisfactory experiments have been made in this respect. Turbine designers customarily assume $b = 2d$, or $\frac{d}{b} = \frac{1}{2}$.

Putting this into our equation, and also 0.47 for f_v, and 0.97 for f_c, we obtain

$$\tan \beta = \frac{n\ K_t}{408} \qquad (14)$$

Thus we see that the minimum possible angle β is in direct proportion to the number of buckets used and to the value of K_t, which is a proof of the statement previously made, that for efficiency the number of buckets should be made as small as possible, because the discharge loss increases with increasing β.

The true or lateral discharge velocity of the water, c' in Fig. 4, is

$$c' = v' \tan \beta = v \tan \beta = \frac{n\ K_t}{429.36} \frac{d}{b} f_c \sqrt{2 g H}$$

and the discharge loss, in terms of the energy supplied, is

$$\frac{(c')^2}{2 g H} = \frac{1}{2 g H} \left(\frac{n\ K_t}{429.36} \frac{d}{b} f_c \sqrt{2 g H} \right)^2 = \left(\frac{n\ K_t}{429.36} \frac{d}{b} f_c \right)^2 \qquad (15)$$

For $\frac{d}{b} = \frac{1}{2}$ and $f_c = 0.97$, we obtain

$$\text{Discharge loss} = \left(\frac{n\ K_t}{866} \right)^2 \qquad (16)$$

The discharge loss varies as the square of the Type Characteristic and as the square of the number of buckets, if the wheel is designed closely according to theory, i. e., if β is made exactly equal to the required minimum.

NUMERICAL EXAMPLE.—Take a 2½-in. jet and assume that, as K_t varies, the shape of the buckets is altered so as to get in each case the least discharge loss which can be obtained by using a certain number of buckets (the number of buckets being reduced to that required in order that loss by imperfect reaction may be zero up to $K_t = 5.0$, and 2½% at $K_t = 6$). Assume further that, at $K_t = 3$ or $D = 18d = 45$ ins., the wheel efficiency is 85%, and that the loss due to bearing friction, resistance and friction in the buckets remains unchanged. Then the following table can be figured:

The discharge loss and loss at reaction, and

Wheel diam in ins. D	Ratio Wheel to jet D/d	Type Char. K_t	No. of Buckets n	Discharge Angle tan β	Discharge Angle β	Discharge Loss Fraction of Input $(c')^2/2gH$	Discharge Loss Excess over 45° Wheel	Loss due to Imperfect Reaction	Efficiency
45	18	2.982	20	0.1460	8° 18′	0.0453	0	0	0.85
40	16	3.355	18	0.1479	8° 25′	0.0465	0.0012	0	0.8488
35	14	3.835	17	0.1597	9° 4′	0.0541	0.0088	0	0.8412
30	12	4.475	16	0.1754	9° 57′	0.0653	0.0200	0	0.8300
27.5	11	4.88	15	0.1793	10° 10′	0.0683	0.0230	0	0.8270
25	10	5.37	14	0.1842	10° 26′	0.0720	0.0267	0.01	0.8133
22.5	9	5.97	13	0.1902	10° 46′	0.0767	0.0314	0.025	0.7936

the total efficiency, are plotted in Fig. 6 from this table.

The above-given theory may be somewhat academic, as the angle β is never made exactly equal to its minimum value but for safety is made somewhat larger (in good standard buckets, for not too high values of K_1, we find β about 10°). Also we scarcely would design a new bucket for each new value of K_1, but would use the same bucket for different wheel-diameters. Nevertheless this theory and the curves in Fig. 6 will be reliable guides for the turbine designer both in making efficiency guarantees and in standardizing impulse-wheel buckets.

Rates for Electric Current Furnished by the Municipal Plant of Pasadena, Cal.

The low rates for electric current recently established by the Municipal Lighting Works of Pasadena, Cal., have attracted attention in various parts of the country so that it seems of interest to publish the rates here with a few operating statistics, taken from the last report of Mr. C. W. Koiner, General Manager, for the year July 1, 1908, to July 1, 1909. The rates may be arranged in the accompanying table.

PASADENA ELECTRICITY RATES.

	Incandescent Lighting.	Arc Lighting.	Power.
Up to 100 KW.-hrs. per mo.	7 cts.	6.75 cts.	4 cts.
100 to 500 " "	6 "	5.75 "	2.4 "
500 to 1,000 " "	5 "	4.75 "	.....
1,000 to 1,500 " "	.....	.....	2 "
1,000 to 2,000 " "	4 "	.....	.....
Over 2,000 " "	3 "	.....	.....
1,500 to 5,000 " "	.....	.....	1.9 "
Over 5,000* " "	.....	.....	1.75 "
Over 5,000† " "	.....	.....	1.5 "
Over 10,000 " "	.....	.....	1.5 "

*If used between 5 p. m. and 10 p. m.
†If not used from 5 p. m. to 10 p. m.

The minimum monthly charge is $1 per meter of 1-HP. capacity, or less, and $1 per HP. additional capacity. Minimum for three-phase meters, $2.

The municipal plant is steam-driven, and oil fuel is used. It is reported that when the city entered the municipal lighting business, the rates for the local supply were about 15 cts. per KW.-hr. for small services. This was reduced to 12.5 cts., it is said, until the municipal plant was running, and later to 8.5 cts. A flat rate was established also, but the supplying company was forced to reinstall meters.

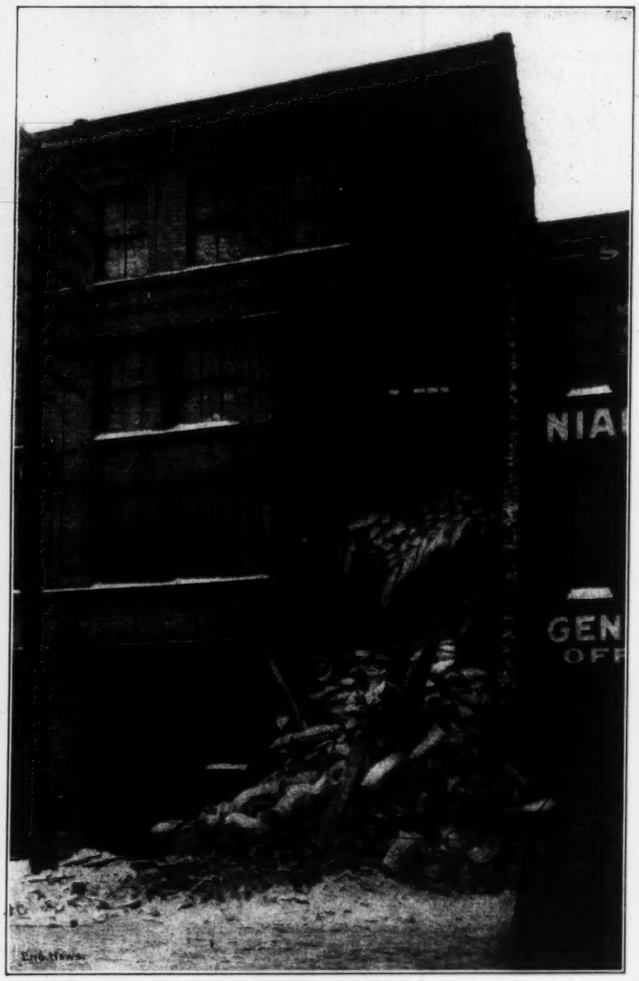
The following figures are arranged from Mr. Koiner's report:

EXPENDITURES:		
Manufacturing—		
Fuel (8,680 bbls. at 92 cts.)		$7,976.39
Lubricants		438.72
Wages at station		3,489.84
Water		114.60
Miscellaneous supplies		381.05
Repairs		342.18
		$12,742.78
Distributing—		
Maintenance and repairs less inventory		4,046.83
Management—		
Salaries		3,192.83
Advertising, etc.		223.40
Supplies		695.23
		$4,111.46
Fixed Charges—		
Interest on bonds		8,500.00
Grand total		$29,401.07
RECEIPTS:		
City street lighting		$30,563.56
City buildings		1,271.51
Commercial		14,046.22
Renewals, deposits, etc.		526.81
		$46,408.10
SURPLUS: Receipts over expenditures		17,007.03
BONDS:		
Issued		$325,000.00
Expended for construction		312,777.73
Unexpended capital		$12,222.27
Redeemed bonds		10,625.00
Outstanding 4%s		265,625.00
Outstanding 4½%s		48,750.00
OUTPUT: Net KW.-hrs.		1,125,791
Arc-lamp hours		2,662.41
KW.-hrs. per bbl. oil		129.81
Manufacturing cost per KW.-hr.		1.13 cts.
Distributing cost per KW.-hr.		0.36 ct.
Management cost per KW.-hr.		0.36 ct.
Total cost per KW.-hr.		1.85 cts.

No attempt has been made toward a complete analysis of the department's operation, nor are all the figures of the last report shown. A few most significant ones have been selected. It will be noted that no allowance for depreciation was made, unless one so views the redemption of $4,375 in bonds from the earnings. This would be 1.42% of the sums expended for construction. The balance of receipts over expenditures, $17,007.08, however, is equal to 5.44% of the construction costs.

The Collapse of an Overloaded Floor.

On Jan. 25 the three upper floors of the four-story building occupied by the Whitney-Noyes Seed Co. at 206 Terrace, Buffalo, N. Y., collapsed under the excessive loading of bags of seed, and, in falling, pushed out the front wall of the building for a width of 15 ft. The resulting damage is shown in the accompanying half-tone. The building was of the ordinary brick-wall and timber-joist and floor construction, and was designed to carry the ordinary loads for a city warehouse. However, it seems that the seed bags had been piled on each of the three upper floors, so that a much larger load than had been intended was applied. The following abstract from the report of the Building Department gives the official explanation of the accident:



COLLAPSE OF A BRICK BUILDING UNDER EXCESS LOAD OF SEED BAGS.

About 15 × 50 ft. of the three upper floors fell and about 15 ft. of the front or east wall, from near the roof line to the ground floor level, collapsed. About 50 ft. of the north wall was also badly bulged. As far as can be ascertained from an inspection made by the Structural Engineer of the Bureau of Building, this building was constructed in accordance with the plans filed in the office of the Bureau on Dec. 17, 1896. The floor constructions were designed and figured safe for uniformly distributed live loads per square foot of 225 lbs. on the ground floor, and 130 lbs. on the three upper floors. Immediately after the collapse many portions of the three upper floors, which were not damaged were found with loads on them ranging from 200 to 400 lbs. per square foot. It is the judgment of the Structural Engineer that the cause of the collapse was the overloading of the floors.

THE WATER FRONT OF ALBANY, N. Y., is to be improved by the construction of concrete walls and boat landings, the laying of pavements, provision of grass plots, and erection of platforms and shelters. A concrete wall 899 ft. long, resting on piles, will be built. Plans and specifications for this work have been drawn by Mr. Walter Melius, City Engineer, of Albany, and bids are to be received until Feb. 21 by the Board of Contract and Supply, of which Mr. Isidore Wachsman is Secretary.

A HYDRAULIC SPEED-REDUCING GEAR devised by H. Föttinger has been built in experimental form by the Vulcan Machine Works of Stettin, Germany. The "Schweizerische Bauzeitung" of Dec. 25 notes that the gear consists of a hydraulic turbine-pump surrounded coaxially by a hydraulic turbine set in the same transverse plane. Apparently a ring of fixed vanes between impeller and runner acts simultaneously as delivery guide-buckets for the pump and entrance guide-buckets for the turbine. The dead discharge water from the turbine returns to the pump suction. Reversal is accomplished, it seems, either by using a separate gear for each direction or else by changing the direction of the fixed vanes so as to make the turbine run in opposite direction to the pump. This gear is intended for getting relatively slow speeds from a high-speed steam-turbine, as in ships. The steam-turbine would be connected to the impeller shaft, while the hydraulic turbine is seated on the propeller shaft.

An experimental gear showed 83% efficiency when delivering 182 HP., but in another test at higher speed (1,750 r. p m.) it delivered over 500 HP. (efficiency not stated) when driven by a Curtis turbine of 500 HP. Considerable economy in space and weight, and some saving in power, are claimed for the gear, as compared with direct steam-turbine drive in ships.

AN INSPECTION TRAVELER and footwalks for inspection have been provided on the large railway and highway bridge over the Vistula River at Marienwerder, in eastern Germany (described briefly in Eng. News, Oct. 22, 1908, p. 460). For the top chord a footwalk is hung just below the top chord, supported on short cross-beams hung from the chord and having a pathway on either side of the chord. The floor and bottom chord are taken care of by a little suspended traveler under the floor, consisting of a U-shaped steel framework whose short vertical legs carry each a pair of wheels running on a track beam bracketed out at the lower edge of the chord. A handwheel with chain drive to one of the bearing wheels enables the carriage to be run along the bridge. The steel framework is floored with plank, giving a transverse platform under the bridge about 4 ft. wide and about 50 ft. long, reaching across the full width of the bridge.

A CENSUS OF MANUFACTURES to cover the year 1909 has been begun by the U. S. Bureau of the Census. The work is under the direct charge of Mr. William M. Steuart, Chief Statistician for Manufactures. Ultimately some 1,800 special agents will be employed. We quote from a circular issued by the Census Bureau as follows:

As there is a general interest in the subject of the comparative importance of the cities, states and territories with reference to the larger selected industries, it is exceedingly desirable that, from the standpoint of civic pride alone, the manufacturers throughout the United States should furnish the data without delay in order that the industrial centers in which they operate may be completely and correctly represented in the statistical tables. Every manufacturer is therefore urged to cooperate promptly and fully with the Bureau of the Census.

Mr. E. Dana Durand is Director of the Census Bureau.

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We have often pointed out the failure of American municipalities to treat the refuse-collection and disposal problem as a businesslike proposition. In recent years a few cities have referred the subject to engineers or engineering commissions for careful investigation and report, notably Milwaukee, Columbus, O., and New York City. In the latter part of 1908, Ex-Mayor Hibbard, of Boston, referred the somewhat complicated question of garbage and refuse disposal in that city to a commission, and after the report of the commission in 1909 he created still another commission to make further investigations. From our abstract of the report of the second Boston commission, published elsewhere in this issue, it will be seen that that commission included men eminently qualified to consider the engineering and sanitary questions involved, as well as the business and labor interests of the city.

Notable features of the Boston report which will doubtless appeal to many of our readers are (1) its arguments for permitting householders to deposit all classes of refuse in one receptacle, thus making possible a single collection in place of the present separate collection of (a) garbage, (b) ashes and rubbish, and (c) in some parts of the city salable and readily combustible rubbish; (2) the burning of the mixed refuse in high-temperature destructors of the British type, with the possible utilization of heat; (3) putting all the work of collection and disposal in the hands of a single contractor; (4) an outline of the most important features of the contract for doing the work as suggested.

In arguing for the single-collection system, with incineration of the whole product, the commission seems to have overestimated the possible nuisances and dangers to health that may occur by the admixture of organic matter with ashes when an attempt is made to collect garbage separately. This possible nuisance and danger is for the most part taken for granted.

The committee also takes it for granted that a reduction plant must be located at a point remote from population, but that the refuse destructors need not be so placed. It is true that American experience points to the advisability of locating reduction plants at some remote point, but we have very little American experience to indicate that furnaces or destructors for burning garbage can be located in thickly settled districts with that freedom of objection which seems to prevail in Great Britain and in the continental countries.

We do not mention these points so much for the purpose of taking serious exceptions to them, as to call attention to the views formulated by this able commission after careful study of the garbage and refuse-disposal problem in Boston and probably with comprehensive knowledge of experience elsewhere. The arguments advanced by the commission in support of its recommendations are fairly put. We should add that the possible advantages of a garbage-reduction plant combined with a refuse destructor for wastes other than garbage are recognized, but with the proviso that the ownership and operation of the plant should be in private hands.

It is interesting to note that the labor-union representative on the committee, while agreeing with the other members on all other points, dissented as regards the sweeping recommendations for the contract as against the day-labor system. His brief but dignified statement in support of his views is given at the end of our abstract of the report proper of the commission and is worthy of consideration.

It is hardly necessary to say in conclusion that the report of the commission is a valuable contribution to the scanty literature of refuse collection and disposal in America, particularly when taken in conjunction with the report of the first commission.

In the current discussion as to the causes for the increased cost of living, the railways have come forward with the prompt and emphatic plea of "Not guilty." While prices of most of the necessaries of life have risen greatly during the past ten years, the rise cannot be laid to an increase in the cost of transportation. In proof of this are quoted the statistics of the Interstate Commerce Commission, which show an average railway freight rate in 1897 of little less than four-fifths of a cent per ton-mile. In 1908 this ton-mile rate had been reduced to about three-quarters of a cent. The average prices of 96 commodities are shown by Bradstreet's to have advanced in the twenty-year period from Jan. 1, 1890, to Jan. 1, 1909, an average of 21.4%. If the freight rates had increased during this period at the same rate, the railways would have received from the public about 243½ million dollars more in 1908 than they actually did receive.

While railway freight rates have been reduced, the price of railway supplies has advanced, and necessary advances in wages to keep pace with the cost of living have enormously increased railway operating expenses.

It may well be asked how it is possible that the railways can sell transportation at a profit to-day at a lower price per ton-mile or passenger mile than was charged ten years ago, notwithstanding the fact that everything the railways have to buy, including labor, has advanced in price from 20 to 100%? The answer is first, that the volume of traffic has greatly increased, and this increase raises the earnings much faster than it raises the operating expenses. In the second place, it is probable that the average freight rate is affected by the enormous growth in long haul bulk freights, particularly soft coal traffic which is carried at very low rates. Of great importance also is the improvement in operating methods, such as the use of large capacity cars and heavy locomotives. The economies resulting from these improved methods have benefited the public even more than the railway stockholders.

A useful study of the relation between typhoid fever death rates and the character of the local water-supplies in different parts of Illinois has been made by Mr. Edward Bartow, Director of the Illinois State Water Survey. Elsewhere in this issue we publish an abstract of a paper summarizing these studies. While the broad general conclusions of the paper are doubtless well founded, it seems desirable to call attention to the fact that all causes for variation in typhoid rates throughout the state have been ignored except those pertaining to the character of local water-supplies. Any other course would have been very difficult and perhaps impossible in connection with so broad a survey of the subject as this. At the same time, it must be remembered that there are many other factors than water-supply that would cause variations in the typhoid rate in various communities and at various dates in the same community.

It is easy to raise questions that cannot readily be answered. Nevertheless we cannot refrain from asking whether the much higher typhoid rates prevailing in the southern as compared with the northern counties of Illinois are due in considerable part to the same general causes, whatever they may be, as produce high typhoid rates throughout the greater part of our Southern States.

We regret the necessity of calling attention to one other factor which has an important bearing upon these Illinois figures. Illinois is not one of the registration states as recognized by the U. S. Bureau of the Census. That is to say, its laws governing the registration of vital statistics are such, in fact and in administration, that the state is not credited as recording as many as 90% of the total deaths that occur within its limits. This being true, it is probable that many typhoid deaths are not recorded, and that the completeness of the typhoid records varies materially in different parts of the state. All this may not materially affect the broad general conclusions drawn by Mr. Bartow, but they should certainly be taken into account by any one who considers his figures in detail. We make this statement, not so much to throw doubt upon the value of the figures, as to emphasize the desirability of action on the part of the State of Illinois that will place it within the registration area.

An apartment house and a factory building in Philadelphia were burned recently, killing eight or ten people. Both structures were thoroughly non-fireproof. The local newspapers in commenting on the fires make a demand for stringent fireproofing requirements. The Philadelphia "Press" says editorially:

> No building should be erected in the central part of a city that is not fireproof. No building intended to house a large number of human beings should be allowed anywhere unless it is made fireproof throughout. . . . It should be adopted as a municipal policy that the quick-burning wooden interiors must go and fireproof buildings take their place.

These are sound, progressive sentiments. One might expect them to be quite general, too, in view of the advancing knowledge of fire dangers and fire losses. Yet we find that the city which should know the fire danger best, San Francisco, has just enacted a new building law whose provisions concerning fireproof construction are highly reactionary and danger-breeding. We have abstracted them in this issue to make this fact clearly apparent from the wording of the law itself.

The San Francisco enactment is not wholly remarkable, however. A Toronto newspaper recently on the occasion of a small school fire seriously raised the query whether it is necessary to build public schools fireproof. It remarked that fireproofing would add to the cost, whereas the available moneys for school building are already too scanty; by providing more stairways, this paper says guardedly, the fire danger in schools is much reduced; taxpayers should consider not only the desirability of thorough fireproof schools but also their greater cost. With such views publicly promulgated it is not so hard to understand the San Francisco law permitting schools to be built with wooden interiors and non-fireproof stairs, permitting stores and warehouses to have wood interiors with unbroken floor areas of alarming size, etc. Fireproof construction evidently has not yet achieved proper recognition. In the matter of theaters the awful lesson of the Iroquois struck

home, as the San Francisco law again proves, but the lesson of the Collinwood school fire and of the great conflagrations of recent years is largely unheeded.

In discussing certain phases of the street railway situation in St. Louis, the "Republic" of that city recently observed:

> There are definite service requirements laid down in the franchises and by general ordinance, but no official or board is charged with seeing to it that the requirements are lived up to. In certain matters it is notorious that the breach is the rule and observance the exception.

It is a weakness of American government, both state and local, that altogether too much reliance is put in the mere placing of laws and regulations upon statute and ordinance books, and that far too little provision is made for inspection and general administration to see that legislation enacted is enforced. This has been particularly true of various franchise provisions of public-service corporations. These franchises generally contain a number of stipulations regarding the character of the service to be rendered to the public, but very seldom indeed is there any systematic and efficient means of seeing that the provisions are carried out.

The newspaper quoted endorses the suggestion of Mr. Frederick W. Lehmann, Chairman of the Board of Freeholders (a body created for revising the city charter of St. Louis), to the effect that the regulation of the street-railway service of St. Louis should be specifically delegated, under the revised charter, to either the Board of Public Improvements or a special board created for that purpose. Speaking of type of car and overcrowding of cars as matters needing regulation, the "Republic" observes:

> If the remedy lay with a board of transportation experts appointed by the Mayor a much truer balance between popular demand and operating possibilities would be struck than at present.

It certainly is very desirable that it be the specific duty of some city official or officials to see that the provisions of various franchises are carried out in the interests of the public. It seems questionable, however, whether this alone is sufficient. The various public-service companies upon which the people of our cities, large and small, are now so dependent, need at least some measure of regulation by properly-constituted state authority, like the Gas and Electric Light Commission of Massachusetts, the Public Service Commissions of New York State, or the Railroad Commission of Wisconsin (the jurisdiction of which last has within a couple of years been extended to practically all public-service corporations in the state)

It happens not seldom, in the experience of an engineer engaged in public work, that unjustified charges of incompetency or corruption are made against him. A correspondent sends us a newspaper report of proceedings in a municipal council in Pennsylvania. A suspicious councilman was discussing with the local city engineer the expenditures on a certain job of retaining-wall construction. The councilman, after various caustic and insulting remarks, finally declared that in his opinion there was grafting in connection with the measurement of the work by the engineer. To this formal charge the city engineer made the following prompt reply:

> Councilman B., I will agree to submit the measurement of that work to Mr. L. [the engineer of a local manufacturing company]. If he does not find the amount of work to be just what I have reported it to be, I will agree to pay his bill and resign my position as city engineer, *provided* that if he does find my measurements to be correct, you will pay his bill and will resign from the Council."

The proposition was not accepted.

The Pittsburg Sewage Purification Orders.

Probably no state in the Union has entered upon so comprehensive a campaign against stream pollution as has Pennsylvania. This was made possible by new and much needed legislation enacted a few years ago, but the actual credit for the work is due to the knowledge and tactfulness of Dr. Samuel G. Dixon, who was appointed State Commissioner of Health soon after the legislation went into effect. Dr. Dixon has been ably seconded by Mr. Herbert F. Snow, M. Am. Soc C. E., Chief Engineer of the Department.

Dr. Dixon has been able to secure a strong measure of control of stream pollution through statutory provisions which require that all plans for sewer extensions involving the discharge of sewage into the waters of the state must be approved by the Commissioner of Health before they are carried into effect. This requirement is so broad that little if anything can be done in the way of extensions to sewerage systems, at least if they involve new outlets, without the approval of the State Department of Health. By conditioning his approval upon the filing of comprehensive plans for the sewerage and sewage disposal of the whole drainage district, or of the whole city concerned, Dr. Dixon has been able virtually to dictate just what each city shall do in the future in the way of sewerage and sewage-disposal improvements. Although we say "dictate," we do not mean to convey the idea that he has been dictatorial. His orders or decrees, as the permits granting applications for sewer extensions may be called, look to making all further sewerage and sewage-disposal work conform to a definite plan, with possible provision for future purification. Or to put it differently, the permits are not sweeping orders to adopt some specific means of sewage treatment. Moreover, where conditions require a permit, all the orders issued contain provisions for an extension of time for the filing of plans or the installation of sewage-purification works, if due diligence in carrying out the order has been exericsed up to the date of application for extension.

Elsewhere in this issue we give extended abstracts of three orders or permits issued to the city of Pittsburg. These orders, in brief, require the city to submit plans for trunk sewers and sewage-treatment works by Dec. 1, 1911, and urge cooperation between Pittsburg and a number of outlying municipalities located in the same natural drainage system.

The three permits (one each for as many drainage districts) make up a total of 100 typewritten pages. Each of the drainage districts and each existing outlet is described, oftentimes with comment on its relation to a comprehensive plan. The permits themselves, and information which we have from Dr. Dixon and Mr. Snow, show that the Pittsburg permits are based on extended local studies made in cooperation with the city authorities. We understand that this general plan is followed in the case of each city to which a permit is granted.

As we have already intimated, the permits lay particular stress upon the necessity of formulating a comprehensive plan for the sewerage and sewage disposal of the city, so that every extension made may conform with ultimate needs both of collection and final disposal. The same doctrine is being impressed upon other municipalities of the state, and cannot fail to be of enormous financial and sanitary advantage to every community concerned. The direction and cooperation of the Pennsylvania State Department of Health will prevent the municipalities of that state from continuing the haphazard methods of sewer construction, with utter disregard to future needs of sewage treatment, which have commonly prevailed not only in Pennsylvania but throughout most of the other states of the Union.

Running through the permits, we note repeated statements regarding the effect of sewage disposal on the use of streams for public water-supplies, which seem to be based on the assumption that sewage purification is an efficient means of protecting such supplies. Inasmuch as these permits are in the nature of orders to submit plans for sewage treatment which must yet meet the approval of the Pennsylvania State Department of Health, it may of course be that the Department will insist upon radical measures of sewage purification wherever the effluents are to be discharged into streams above water-works intakes. We do not doubt that when the practical problem of saying just what should be done to sewage to virtually convert it into drinking water confronts the State Department of Health it will display a sense and tact already exhibited in laying down its requirements. We presume that the Department will hardly go so far as to expect or require that sewage will be so highly purified as to render it safe for communities below a sewage-works outlet to draw water from even so large a stream as the Ohio River without purification. Obviously, the problem of water purification will be lessened to a considerable extent with the removal of even a portion of the bacterial contents of sewage. It is equally obvious that any financially practicable means of sewage purification yet employed on a large scale will not be a perfect safeguard against bacterial infection, and that if such a safeguard is to be provided it must be either some high-grade secondary system of sewage filtration or the use of a disinfectant like the bleaching-powder or hypochlorite of calcium or sodium which is now being used on an increasingly large scale in water purification and which on a small scale has proven effective in sewage treatment.

To an outsider it seems as though the municipalities of Pennsylvania are being pressed to adopt measures of sewage purification almost to the exclusion of pressure to look after the sanitary quality of their water-supplies. This, we presume, is not really the case. It should be remembered that Philadelphia and Pittsburg, as well as some of the smaller but still important cities of the state, already have water-purification works for the whole of their populations, either in operation or nearing completion. In addition to this, the State Department of Health has from time to time had large forces of inspectors in the field looking after the pollution of water-supplies.

A thing which it seems to us the State Department of Health has overlooked, at least to a large extent, is the fact that there is an end, temporary though it may be, to the funds that municipalities can provide for public improvements. Sewage and water-purification works are by no means the only sanitary improvements which are demanded in the interests of public health, and expenditures for these and other health-protective measures form only a small part of the demands upon the municipal treasury. Health considerations should certainly come before most if not all others, but nevertheless there is great need for a comprehensive municipal program for each municipality. The sewerage and sewage-disposal permits issued by the Pennsylvania State Department of Health, exhaustive as they are in their view of the subjects immediately concerned, seem to take no cognizance whatever of other municipal necessities, with the exception of the relation of sewage disposal to public water-supplies (chiefly of other communities). Doubtless, when the municipal authorities ask for extensions of time to complete plans for sewerage and sewage-purification systems, or for postponement of dates at which those systems must be completed and in operation, the Department will take into account any representations made by the various cities as to conflict between the monetary demands for these and other needed public improvements.

At the same time, we cannot but wish that it were possible for the Pennsylvania and for other state departments or boards of health to make broader surveys of municipal health needs, instead of taking up one problem alone quite regardless of the others that are surrounding the city concerned. Perhaps this will be more feasible as time goes on. It is certainly true that in many sections of the country improper means of sewage disposal and consequent stream pollution have gone to such lengths as to make it imperative that remedies be provided almost regardless of other local necessities. All that we have said along these broader aspects of the Pennsylvania stream-pollution campaign should be considered in the light of the fact that, after all, one of the chief things being insisted upon by the Pennsylvania State Department of Health is that whenever a city does propose to extend its sewerage system, a broad view of the subject should be taken and comprehensive plans should be made for the future. Oftentimes, little or no more

nitial expense is involved in a comprehensive, ar-looking plan than in one which is but partial nd for the immediate present; while, in the long un, it is evident that comprehensive planning or the future means saving of money and conervation of health.

A Remarkable Testimonial to the Work of Civil Engineers.

We believe every civil engineer engaged in Government work under the Corps of Engineers will feel a glow of pride upon reading the letter which we print below from Gen. Clinton B. Sears, recently retired from the Corps of Engineers after more than two-score years of service. As for the engineers who have had the honor of serving under General Sears, they will be justified in having his letter engrossed and framed. And the engineering profession as a whole, we are sure, will highly appreciate General Sears' manly and generous testimonial to the character of work done by the U. S. Assistant Engineers, which comes at a time when it can be of greatest service.

Sir: I have just read your editorial in your issue of Jan. 27, entitled "Civil Engineers on River and Harbor Work," etc, and fully agree with the statements, arguments and recommendations therein set forth. I am glad to know that an effort is being made in behalf of one of the most deserving bodies of public officials in the service of the Government.

With the object of aiding this movement, I desire to bear witness to the great ability, the strict integrity and the faithful discharge of all duties assigned to them, which have always characterized the Civil Assistants serving with the Corps of Engineers. Having served in all grades from second lieutenant to Colonel of Engineers, with 41 years' experience and with stations in all parts of the United States, from the Atlantic to the Pacific, from the Lakes to the Gulf and in the Philippines, with all the varied duties on fortifications, surveys, rivers and harbors, roads and bridges, lighthouse work, etc., incident to the Engineer service, and as member of many boards passing on plans, often primarily prepared by our civil engineer assistants, I have had extended opportunities to meet personally and study the work of a large number of them, and through association with other engineer officers, to learn the characters and abilities of many more.

In all these years and with all this acquaintance, I do not recall a single instance of any dereliction of duty, any lack of sterling honesty, or any failure to meet fully the requirements of the work entrusted to them.

I have had them at work in immediate local charge of large and important projects; have entrusted to them great sums in cash; and have paid out millions of dollars on vouchers certified by them. I have had them working in the field in the coldest winter, with the thermometer at 30° F. and below; in the humid tropics, with the depressing and exhausting climate incident thereto; in arid deserts; in altitudes so great as to render physical exertion difficult; in swampy regions, reeking with malaria and swarming with insect pests; often for years at isolated and desolate stations; daily risking health and life on ocean and lake and in swift river currents, and in placing and operating massive and complicated machinery, and they have always "made good."

I have often been indebted to them for original and valuable suggestions, and have frequently adopted without modification, important projects submitted by them, and have always given them full credit.

My rule has been to hold my assistants to a strict responsibility and then give them a free hand, interfering as little as possible with details, and never harassing them in their control of men and methods of work. This course has been fully justified by results.

With such record of efficient service, there can be no doubt that there should be higher rewards and promotion in the upper grades to positions with greater remuneration and responsibility, and I hope the effort in this direction will meet with abundant success.

In this connection, I desire to pay my tribute to the zeal, ability and fidelity of the chief clerks serving with our engineer officers. We have had not only to look closely to our technical duties, but also to our money accounts. For the latter an able and faithful chief clerk is of the greatest assistance. He must be thoroughly conversant with all the forms of official records and returns; with the rules and regulations of the War and Treasury Departments, and especially with the many and various rulings and opinions of the Comptrollers and Auditors, and he has to verify and prepare vouchers and checks covering great sums, and a multiplicity of details.

After over 40 years' experience with many chief clerks, involving the expenditure and accounting of millions of dollars, I have not been out of pocket one penny through their fault, and my accounts have been examined, found correct and closed, by the Treasury Department. I can pay them no higher tribute than the statement of this fact.

Very truly yours,
Clinton B. Sears,
Brig.-Gen., U. S. A. (Retired).

Newton Center, Mass., Feb. 2, 1910.

LETTERS TO THE EDITOR.

Heavy Rate of Rainfall at North Sydney, N. S. W.

Sir: Reading over some back numbers which have accumulated during a press of work I note in your issue of Nov. 18, 1909 (p. 551), a list of heavy precipitations at various points.

I remember a "Southerly buster," to use a local name which occurred in North Sydney, N. S. W., on Feb. 11, 1894 or 1895, in which 3 ins. of rain fell inside of 30 minutes. This is by far the heaviest rate of precipitation that has ever come under my observation.

Yours truly,
Ernest H. Wilcox.

Bryson Block, Los Angeles, Cal., Jan. 28, 1910.

Empirical Formula for Crown Thickness of a Reinforced-Concrete Arch.

Sir: Several formulas have been printed for obtaining an approximate crown thickness for reinforced-concrete arches, but the following, used in our office, I have never seen in print:

Let $r = \frac{S}{R}$.

R = rise in ft.

S = span in ft.

t = crown thickness in ins.

Then $t = \frac{(20 - r)}{10} + \frac{S}{5} + \frac{75}{2\,S}$.

The thickness is always in exact inches and when the formula gives it in fractions of an inch, the next larger inch is taken.

The formula was derived by Mr. Ernest McCullough, formerly Chief Engineer for this company. The conditions of loading are two feet of fill over crown, the live load being a 15-ton steam roller.

Yours very truly,
C. O. Powell, Engineer,
Northwestern Expanded Metal Co.

Chicago, Jan. 18, 1910.

The Inventor of the Direct-Acting Explosion Pump.

Sir: The appreciative notice in your issue of Dec. 2, 1909, re, "An Unique Direct-Acting Explosion Pump," interested me, first, from the fact that the United States Patent Office accords to me (after a more than usually prolonged and searching "examination"), inventorship, in fact pioneership, in this new art or process, and specifically in this device and the method underlying it, and secondly, in that the article illustrates and justifies a pet theory of invention, propounded in a series of widely copied and much criticized articles under the caption, "Is the Inventive Faculty a Myth?" published some 12 or 15 years ago. I took the position that "invention" instead of being a creative act, was a purely logical analysis and synthesis. The London "Engineer," or "Engineering," I have forgotten which, in an elaborate criticism, made it perfectly plain that the writer of the articles could not possibly be an inventor or he would known better and, further, that my analysis of the "ideal heat motor," used as illustration of my theory, while interesting led nowhere. A comparison of that analysis and the theory of the operation of this departure in heat motors will prove worth while I feel sure.

One of my minor applications for a patent on this subject, issued Oct. 12 last and bearing the number 936,677, contains the following interesting quotations:

Application filed July 25, 1904. . . . As further illustrating the scope and extent of the invention underlying the construction herein set forth, reference is here made to application filed Oct. 13, 1902, for a new method or process under the title of "Utilizing Heat Energy," Serial No. 127,172, and an application for an apparatus of the same general type under the title of "Utilizing Heat Energy," filed Oct. 13, 1902, Serial No. 127,173.

Besides its peculiar desirability in the present form, the omission of valves is desirable in any pump, and particularly valves beneath water. . . . Fortunately the characteristics which, under the circumstances of the present disclosure render the presence of valves peculiarly undesirable, provide also, conditions which make them unnecessary. That is to say, the incompressibility and inertia of water may be utilized by proper mechanival provisions to take the place of valves. . . . It will thus be seen that a violent, but controlled surging or pendulum-like oscillation of the water piston takes place. . . . This is a most highly desirable condition as the piston alternately gives and receives energy with practically no loss. Thus the increment of energy due to explosive action is wholly liberated to effect the upward movement of the water in the casing. . . .

It will be observed that in the operation of the device, certain novel, interesting and valuable conditions and functions are present and utilized. The first and most striking is the pendulum-like or surging action of the piston in its unrestricted reciprocation. . . . This utilizes and makes practically effective a condition in which bodies of large mass may be kept in motion with a minimum expenditure of energy. Thus is brought about a condition in which practically the whole explosive increment of energy is liberated for the accomplishment of effective work or, in other words, raising the mechanical efficiency of the transforming apparatus to practically theoretical perfection. . . . .

As therefore this disclosure introduces broadly novel principles, functions and effects for the utilization of the energy of explosive action and their application to the raising and moving of water, it is not desired that the invention be limited to the forms, proportions or arrangements of parts herein illustrated or any particular mechanical expression thereof, but I desire to claim the invention or inventions herein, in the broadest manner as a pioneer invention.

In closing, it gives me pleasure to be able to confirm Prof. Unwin's reported tests of efficiency and economy, my experience shows an efficiency greater even than his.

William H. Smyth.

"Fernwald," Berkeley, Cal., Jan. 20, 1910.

Will the Panama Canal Pay?

Sir: Will you spare a little of your valuable space to a Southerner for a brief criticism of an enterprise that is popularly supposed to be of inestimable value, present or prospective, to the South, viz.; the Panama Canal? It seems to me at the very least open to question that it will be so. Yet one is almost put down as being disloyal to his section of the country if he even hints of this canal being other than a piece of work of incalculable prospective benefit to the southern states.

It appears now that the cost of this piece of work, the Panama Canal, is going to be nearly $400,000,000. It was estimated before the canal was started that the probable traffic at the time of opening would be about 6,000,000 tons (6,401,332 tons in 1914, to be exact). It is about 46 miles across the isthmus and, as is well known, freight has been moved on the railroads of this country for 1 ct. per ton-mile or less, the exact figure need not be stated here, for we will take it at one cent for the purpose of this argument. Then for 46 miles the cost of moving freight by rail across the isthmus would be 46 cts. per ton. To make easy figuring call it half a dollar. Six million tons a year would then cost $3,000,000 to move by rail across the isthmus, exclusive of loading and unloading at the termini. Such loading and unloading ought not to cost, it seems to me, more than 25 cts. a ton at each place and that would be another half-dollar a ton or another $3,000,000 to add to the previous $3,000,000, or six million dollars in all.

Why then build the canal at a cost of hundreds of millions of dollars for the use of a partly yet-to-be-developed traffic? The interest on 400 million dollars at 3% is 12 million dollars a year, to which add 3 million dollars for maintenance of the canal, making an annual charge of 15 million dollars, as against the above estimated six million dollars for handling in ships that would tranship to railroad at the isthmus—and if the traffic proved to be only 4,000,000 tons a year as against only four million dollars.

This argument is only to show that the canal is of very doubtful profit commercially. If the canal is unprofitable to the nation and if traffic does not gravitate to it naturally and without legislative interference, then its value to the South will be small.

Now as to traffic in the future. Wellington's argument as to spending money to provide facilities for traffic in the future (see his "Railway Location," page 80 et seq.) applies to the building of canals quite as well as to the building of railways. If your estimate of future growth of traffic on this canal is right (Eng. News, Vol. 55, p. 448, April 19, 1906) there will be 15½ million tons to move in 1945, to move which at $1 a ton across the isthmus by rail (terminal charges included) would cost about the same as the interest and maintenance charges on the canal. But 1945 will still be 30 years off at the opening of the canal in 1915, and the amount of 400 million dollars at 3% compound interest for that time is 972 million dollars, which is what the canal will really have cost in 1945 for first cost and interest, from which should be deducted its earnings during that period, maintenance deducted. The Suez Canal in 38 years got up to 13½ million tons traffic in 1908.

The building of the Panama Canal is going to be used as an argument for waterway improvement within the United States, and in comparison with what that canal cost it is going to be argued that the expenditure of $200,000,000, say, for a waterway from Chicago to New Orleans, for instance, is a "mere bagatelle" and those who do not approve of such expenditure will be called narrow-minded, niggardly, stingy, tools of the corporations, railroad puppets, bought up, etc.

This 1910 is a year of big things, but poverty still abounds and one does not have to go far to find it. The burden of taxation should not be increased for there are burdens enough that are inevitable, and this is to some extent an "evitable" or avoidable burden.

For one, I favor the government doing the minimum possible and keeping out of industrial undertakings:

water supply for cities; operating street railways or owning them; building "good roads" or bad ones either—and a road built better than the traffic justifies is a bad one no matter how smooth and beautiful it may be. In brief, I am a follower of Herbert Spencer.

I am in favor of progress and improvement, but against injustice as far as injustice may be avoided. For development, but let it be through self help.

Respectfully, A. P. C.

Nashville, Tenn., Jan. 25, 1910.

[Our correspondent's conclusion that the Panama Canal will pay only trifling interest on the investment necessary to build it is in all probability correct. Nevertheless there are *possibilities* that the growth of traffic in the future will be very considerably greater than what has been conservatively assumed in past calculations. The lumber from the forests of British Columbia—the last great body of virgin soft wood timber in the world—may furnish a very great amount of traffic through the canal. There is a possibility, too, that future discoveries of coal or iron ore or phosphate or other bulky mineral deposits in the Andes may provide some such vast traffic through the canal as that which now flows past Sault Ste. Marie.

In the comparison between rail and water transport across the Isthmus, our correspondent probably underestimates the cost of transhipping from ships to railway cars and vice versa for rail transit across the Isthmus. Bulk materials such as grain or ore can indeed be transhipped for the figures given or much lower; but general merchandise, and even coarse freights such as lumber, cement, castings, brick, tile, etc., cost very much more to transfer, when the damage done to the goods is taken into account.

Our correspondent may recall that the public took very little real interest in Isthmian Canal matters until the Spanish War of 1898, and the spectacular voyage of the "Oregon" round Cape Horn. It was that which brought about the construction of the Isthmian Canal; and if the canal saves the United States every year the cost of constructing and maintaining one or two battleships and cruisers, it will be a paying investment.—Ed.]

Notes and Queries.

In connection with the overflowing of the Seine at Paris recently, Mr. A. W. Bedell, of Chappaqua, N. Y., writes:

I have thought of a way of possibly alleviating such troubles by increasing the discharge of the river. Over some rivers there are stone arch bridges having a great number of piers which produce end contraction of the water flowing through. If this contraction, and sudden expansion at the lower side, were suppressed, the discharge would be increased somewhat—enough, perhaps, to keep the water level within safe limits. Piers having ogival ends would not need any attention; but those that are flat could be improved by setting temporary pointed cribs above and below. Just what would be gained by this depends upon local conditions at the time. Sometimes it might control what would otherwise be a flood; and when a few feet of water means a large loss of property, industry, and life, although the work would be attended by some difficulties, it might be worth considering, and the expense be justified.

In the editorial in our issue of Jan. 27 (p. 103) we suggested that engineers and engineering organizations appeal to members of Congress for favorable action on the proposition to give greater responsibility and better standing to the U. S. Assistant Engineers engaged on River and Harbor Work. For the benefit of any who may desire to do this we print the following list of members of the two House committees before which the bills relating to the subject are likely to come.

Committee on Rivers and Harbors: D. S. Alexander, New York, Chairman; G. P. Lawrence, Massachusetts; J. H. Davidson, Wisconsin; James McLachlan, California; H. O. Young, Michigan; H. C. Woodyard, West Virginia; W. A. Rodenberg, Illinois; W. E. Humphrey, Washington; M. B. Madden, Illinois; C. A. Kennedy, Iowa; J. H. Cassidy, Ohio; J. K. Tener, Pennsylvania; S. M. Sparkman, Florida; J. E. Ransdell, Louisiana; G. F. Burgess, Texas; B. G. Humphreys, Mississippi; J. A. Moon, Tennessee, G. W. Taylor, Alabama; J. E. Ellerbe, South Carolina; C. G. Edwards, Georgia. Committee on Military Affairs: J. A. Hull, Iowa, Chairman; A. B. Capron, Rhode Island; G. W. Prince, Illinois; H. O. Young, Michigan; Julius Kahn, California; J. F. Burke, Pennsylvania; T. W. Bradley, New York; Frederick C. Stevens, Minnesota; D. R. Anthony, Jr., Kansas; C. L. Knapp, New York; C. H. Morgan, Missouri; J. Q. Tilson, Connecticut; J. Wickersham (James), Alaska; Wm. Sulzer, New York; Jas. Hay, Virginia; J. L. Slayden, Texas; Isaac R. Sherwood, Ohio; G. W. Gordon, Tennessee; Ben Cravens, Arkansas; S. H. Dent, Jr., Alabama.

A correspondent inquires whether it is possible to bushhammer or otherwise tool a concrete surface which has not been especially prepared for such a treatment. He thinks that possibly such a tooling will bring to the surface small pieces of stone or gravel which, being so much harder than the surrounding mortar, will not take the tool finish, but will rather draw out from the surface and form small holes.

The original method of preparing a concrete surface for tooling was to place a 3 or 4-in. mortar face against the forms during the concreting, forming with the main body of the concrete a solid mass. This mortar having no coarse aggregate was particularly adapted to a tooled finish, and when so treated, formed a surface quite pleasing to the eye. Of late, however, in many notable structures, among which may be mentioned the Edmonston Ave. Bridge in Baltimore and the Mulberry St. Viaduct in Harrisburg, the tooled finish has been applied to an ordinarily mixed and placed concrete face. The only precaution that has been taken has been to see that no very large stones come against the face of the form, that is, a spaded finish has been used. When such a face is tooled, unless large gravel is used for aggregate, the cuts of the tools make very even lines across both mortar and aggregate and a finish of the highest quality is usually procured.

If any of our readers have had experience which would make them either in favor or against such practice, we would be glad to hear from them.

Steel Penstocks.

By R. A. WRIGHT.*

A necessary feature of many modern hydraulic power plants, perhaps a majority of them, is the penstock, the tube which conveys the water from the upper level, that of the forebay or dam, to the power-house. As in other parts of a plant, the most desirable type of penstock varies with local conditions, which are never exactly the same in any two cases. Penstocks are constructed of steel or wood, or sometimes of concrete. It is not the intention here to enter into a discussion of the relative merits of different types but rather to give a general outline of the principles governing the design of steel penstocks, with a few details, in the hope that they may be of interest to the younger men engaged in this particular department of design. The designs described are taken from actual installations and the tables worked out agree fairly well with current practice and should prove useful to those who have not had long experience, or sufficient acquaintance with actual practice to have gathered this information from their own experience.

DETERMINATION OF SIZE.—The first thing to be determined, of course, is the proper diameter of penstock to suit the requirements of the development, and this is really the most difficult problem of the design because of the large number of factors to be considered. No definite rules can be laid down to cover most of these questions and much must be left to the judgment of the designer, but a general discussion should throw some light on the subject. The principal factors may be outlined as follows: (1) the quantity of water to be delivered to the power plant, (2) the head on different sections of the penstock, (3) the length of the penstock. (4) the nature of the application of the power. (5) accessibility of the site, (6) the design fixed upon for the wheels.

The first factor is determined, usually, as one of the first essentials of the installation, being one of the factors upon which depends the feasibility of the development. Whether the water to be delivered is conveyed by one or more penstocks depends on the quantity of water and the number of units fixed upon for the plant, but this is a question belonging to power-house design and will not be discussed here. The quantity of water having been settled, the size of penstock is fixed by the speed at which it is allowed to run, and this is a point, as stated above, which it is impossible to determine by rule in all cases. A high speed entails considerable loss of head by friction with a consequent low efficiency of the installation as a whole, while a slow speed brings increased cost of construction of the penstock itself. Considering the head, we find that under a low head it is advisable to use a slow speed because the loss of a foot of head by friction is a much larger percentage of the total head than where a high head is available, and because the spouting velocity, and consequently the rim speed of the turbines, being low the water should enter the wheel case at a comparatively low speed in order to secure the best efficiency. Under a high head a slight friction head is not a serious matter and it is better for the efficiency of the wheels that the water should reach them at rather a high speed. In the nature of things, however, it is usually found that longer penstocks are required for high heads than for low.

Of course, the friction head increases with the length of penstock so that lower speeds are desirable for long penstocks than for short ones, other things being equal. The question of water-hammer becomes increasingly important with long penstocks and high speeds because of the great mass of water to be accelerated and retarded, and the greater fluctuations of speed. This may be taken care of to a certain extent by the use of stand-pipes or relief valves, and certainly one or the other of these should be provided on all except the shortest penstocks, but it is well, also, to keep down the speed of water, this being the surest safeguard of all. Consideration should be given to the conditions under which the plant is to operate—pulp grinders, for instance, run

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TABLE I.—FRICTION HEADS OF RIVETED STEEL PIPES.

Formula $H_f = f\frac{L}{D}\frac{V^2}{2g} = 1.55 f\frac{V^2}{D}$ for $L = 100$

where H_f = Loss of head due to friction
L = Length of pipe in feet
D = Diameter of pipe in feet
V = Velocity of water in ft. per sec.
g = Acceleration of gravity
f = A factor — Merriman

Dia	Velocity in ft. per sec.							
Inches	5	6	7	8	9	10	11	12
24	.348	.488	.645	.820	1.005	1.200	1405	1620
30	.264	.369	485	615	755	900	1050	1210
36	.207	.288	380	480	585	700	812	930
42	.166	.231	.304	383	466	.575	670	765
48	.136	.189	.256	322	392	485	562	640
54	.121	167	.228	286	348	430	500	570
60	.104	.151	.198	258	314	388	450	515
66	.095	.132	.180	225	274	339	392	467
72	.084	.121	.164	207	251	297	360	410
84	.069	.100	.130	.170	206	255	295	
96	.058	.084	.109	142	.181	213		
108	050	.071	093	121	.153			
120	043	.061	084	109				

TABLE II.—MAXIMUM PERMISSIBLE HEADS ON STEEL PENSTOCKS, IN FEET.

Dia	Plate - single riveted - eff. 60%							
	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8
30	130	175	220	260				
36	110	145	180	220				
42	90	125	155	185	220			
48	80	110	135	165	190			
54	70	95	120	145	170	190		
60	65	85	110	130	150	175		
66	60	80	100	120	135	160	180	
72	55	75	90	110	125	145	165	
78		70	80	100	120	135	150	165
84		65	75	95	110	125	140	155
96			70	80	95	110	120	135
108			60	70	85	95	110	120
	Double Riveted - Efficiency 70%							
36	130	170	210	260				
42	110	145	180	215	260			
48	95	130	160	190	220			
54	80	110	140	170	200	220		
60	75	100	130	150	175	205		
66	70	95	120	140	160	185	210	
72	65	90	110	130	145	170	195	
78		85	100	120	140	160	180	195
84		75	90	110	130	145	165	180
96			80	95	115	130	145	160
108			70	85	100	115	130	140

TABLE III.—WEIGHTS PER FOOT STEEL PENSTOCKS. (EMPTY.)

Dia.	Single Riveted						
	1/4" Pl.	5/16" Pl.	3/8" Pl.	7/16" Pl.	1/2" Pl.	9/16" Pl.	
30"	72	97	116	137			
36"	86	116	140	165			
42"	99	135	163	192	222		
48"	113	154	187	220	254		
54"	127	172	210	248	286	326	
60"	141	191	234	276	318	361	
66"	155	210	257	304	350	396	448
72"	170	228	280	332	382	432	488
78"		246	303	360	414	467	527
84"		264	326	388	446	502	566
96"			373	444	510	573	646
108"			420	500	575	645	726
	Double Riveted.						
36"	89	120	145	171			
42"	102	139	168	198	229		
48"	117	159	193	227	261		
54"	131	177	216	253	294	335	
60"	146	196	241	284	326	370	
66"	160	216	263	312	359	406	458
72"	175	234	287	340	391	442	499
78"		253	310	369	424	478	538
84"		270	334	398	456	504	578
96"			381	454	520	585	659
108"			428	511	586	658	740

continuously at full gate-opening, while turbines supplying power for electric railways may operate normally at half gate, only opening up wide to take care of an occasional, momentary peak load. In the latter case it would be fair to base the calculation of friction losses on the quantity of water consumed by the wheels at half gate.

The use to which the power is to be applied also has a bearing on this question. For instance an electric power plant, being subject to possible variations from full load to no load instantaneously, would require a larger penstock than a plant using the same quantity of water for driving a number of wheels connected to separate machines, as pulp grinders, and not subject to an instantaneous variation of so large a percentage of the whole power. The type of wheels used may also have a certain influence in the determination of the most desirable speed of water since impulse wheels require a high speed at the entrance to the wheel while reaction wheels require a lower speed. With the scroll-case type of turbine the water enters at nearly the speed of the entrance edge of the wheel buckets or at such a fraction thereof as will be determined by the shape and arrangement of the guide vanes, while such a speed in the case of a cylindrical wheel-case, inclosing, say, a pair of wheels with central draft-tube and the inlet at the side of the case, would set up such eddies as might bring down the efficiency of the plant 50%. Of course it is always possible to change the speed of the water gradually by means of a tapered section of penstock just before entering the wheel-case, either increasing or decreasing the speed to suit the requirements of the wheel, but care must be taken to make such changes very gradual or else an appreciable loss of head will result. Though it is impossible to fix general rules for definite speeds, it is worth while to classify the speeds as characterized by common practice. Low speeds are from 2 to 8 ft. per sec.; medium speeds are from 8 to 12 ft. per sec.; and high from 12 to 25 ft. per sec.

The accessibility of the site may be an important factor in determining the size of the penstock since the erection and transportation of a large penstock may amount to a prohibitive figure, while the probable market for power may be only a fraction of the available power, in which case it would be economy to permit a considerable loss of head by friction in order to reduce the size of the penstock. It will be seen that for the intelligent solution of this problem we require complete information as to the flow of the stream, topography of the site, probable market for the power and financial resources of the promoters. These questions, of course, are fundamental to the proper solution of any power proposition and will have been carefully investigated as the very first step in determining the feasibility of the development.

A little thought leads to the conclusion that, in a given water power development, the most economical size of pipe to install is the one with which the annual costs and charges plus the value of the energy loss in the pipe is a minimum. The size of pipe that most nearly meets this requirement can be found by cut and try methods, though there is a wide latitude of interpretations to the expression "value of energy loss in the pipe." When the head and quantity of water are fixed within narrow limits, as noted before, the solution is greatly simplified. Mr. A. L. Adams, M. Am. Soc. C. E., in a paper before the American Society of Civil Engineers, June 5, 1907, demonstrated

That pipe fulfills the requirements of greatest economy wherein the value of the energy lost in frictional resistance equals four-tenths (0.4) of the annual cost of the pipe.

Many have claimed that this rule has no rigid application, but it is logical and in absence of other determining factors should be employed.

In a hydro-electric plant it may be advisable to compute the size of pipe in this way at the prevailing load, developing the peak load at smaller efficiency. Some designers, on the other hand, may prefer to establish the size of pipe from an estimate of the value of the all-day losses or the average efficiency of operation. In the rare cases when a waterfall is being developed to obtain the greatest possible power and where the cost of installation therefore has only a minor bearing, Mr. Adams' rule cannot have any bearing.

Table I. gives the friction heads corresponding to different speeds of water in penstocks from 2 to 10 ft. in diameter and 100 ft. long, based on a formula given by Merriman.

In calculating the above table f was taken 10% greater than the values recommended by Merriman to allow for the roughness due to rivet heads and for the lap of circumferential seams.

WEIGHT OF PENSTOCK.—Having fixed on the size of penstock we next come to the question of fixing the thickness of the shell to suit the pressure of water to be carried. Most penstocks are constructed of tank-steel plates having a tensile strength of from 45,000 to 50,000 lbs. per sq. in., although for high heads and speeds it is advisable to use the best quality of flange steel. The riveting is done in all styles, single and double-riveted joints being most common, although triple-riveted lap and butt joints are occasionally used. A number of considerations affect the choice of a style of riveting, but it would be safe to say that a majority of penstocks are built with all lap seams, the circumferential seams being single-riveted and the longitudinal double-riveted. This gives a sufficient excess of strength in the circumferential seams to provide for the bending between supports. For heads under 30 ft. all seams may be single riveted, making the spacing in the circumferential seams as great as consistent with securing a tight joint.

Having selected a style of riveting and quality of plate, thus determining the unit strength, we are able to fix on the thickness of plate to be used. In this connection Table II. will be of use, giving the maximum heads under which various thicknesses of plates should be used with various diameters of penstock. The table is based on a fiber stress of about 7,500 lbs. per sq. in. under static load, which is an average figure for ordinary conditions. The table gives values for both single and double riveting based on nominal efficiencies of 60 and 70% respectively. Where more efficient seams or other values of fiber stress are used the head can be obtained by simple proportion.

TABLE IV.—BENDING FACTORS OF STEEL PENSTOCK.

Dia in Inches	Moment of Inertia. Thickness of Plate 1/4"	3/8"	1/2"	5/8"
36	4677	7088	9550	
48	11025	16670	22400	28220
60	21470	32410	43490	54700
72	37000	55800	74800	94000
84	58700	88500	118500	148700
96		131800	176500	221500
	Section Modulus			
36	256	386	516	
48	455	684	914	1146
60	710	1067	1426	1786
72	1021	1535	2049	2567
84	1389	2089	2788	3489
96		2724	3639	4555

Table III. gives the weight of the penstock per lineal foot for either single or double riveting and for various thicknesses of plates. In figuring this table allowance was made for the circumferential seams, based on the most usual width of plates for the different thicknesses, also for over-weight of plates according to the manufacturers' standard table of allowances. The weights given in the table, of course, are for straight pipe—for bends an additional allowance should be made, up to 10% for bends of short radius, on account of the narrow plates used which makes the allowance for circumferential seams an increasing factor.

ACCESSORIES.—The question of supporting the penstock is one which depends to a very large extent on local conditions as well as on the weight and size of the tube itself. Primarily the supports should be solid, consisting of concrete or masonry piers, preferably resting on solid rock, or if a rock foundation is not obtainable the piers should be of such size as to insure stability of bearing. The penstock should be carried on cradles, resting on these piers, a design for which is shown in Fig. 1. This cradle is made of angles with a web-plate and is securely riveted to the

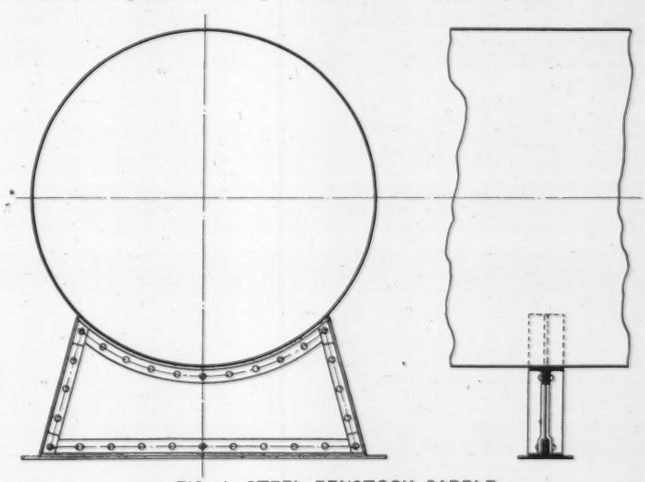


FIG. 1. STEEL PENSTOCK SADDLE.

penstock. To allow for expansion it is desirable to provide oblong holes in the base angles and a steel or cast-iron plate set in the top of the foundation on which the cradle may slide, the joint being well painted with graphite during erection.

The spacing of these supports is susceptible of calculation, assuming the penstock as a girder uniformly loaded, the load consisting of the weight of the penstock and water. The most severe conditions one can impose accompany the assumption of a girder free at the ends. The effect is to produce longitudinal tension in the lower side of the penstock and this stress added to the longitudinal tension of the static pressure of water should not be allowed to exceed the safe tensile strength of the material. The stress due to bending is

$$f_b = \frac{3}{2}\frac{WL^2}{S},$$

where L and W are in feet and pounds per foot respectively, S is the section modulus. The fiber stress (longitudinal) due to static pressure is

$$f_t = \frac{pd}{4t},$$

where p is pressure in pounds per square inch, d is the nominal diameter in inches and t is the thickness in inches. Adding these, for total stress:

$$f = \frac{3}{2}\frac{WL^2}{S} + \frac{pd}{4t}.$$

From this we can get the distance between supports

$$L = \sqrt{\frac{2}{3}\frac{S}{W}\left(f - \frac{pd}{4t}\right)}$$

Taking the double riveted penstocks in Table II. with single riveted circumferential seams, carrying the full heads given, with a maximum fiber stress of 7,500 lbs. per sq. in. and 60% efficiency of the transverse seam, we get the following maximum spans. The figures are for pipes filled with water.

Diameter pipe, ins.	Thickness of plate, ins. ¼	⅜	½	⅝
36	23.6	27.6	....	....
48	24.2	28.6	32.1	....
60	24.6	29.3	33.0	....
72	24.9	29.8	33.7	36.7
96	....	30.4	34.5	37.8

In calculating similar values for particular cases, Table IV. may be found useful. Values of the section modulus for thickness of plate intermediate between those given may be interpolated with sufficient accuracy.

When the slope of the penstock is so great that the longitudinal resultant of its weight will overcome the friction of the saddles on the pier plates and tend to cause sliding, it is necessary to provide solid anchorages. One of these should be close to the wheels so that expansion and contraction of the penstock between the anchorage and the wheels will not disturb the alinement of the latter. A good form of anchorage consists of a heavy concrete pier resting on solid rock and completely encircling the penstock, one or more rings of heavy steel angles being riveted to the shell at this point to obtain a good hold on the concrete. For further security the pier may be anchored to bed rock by means of bolts or rods set in holes drilled in the rock.

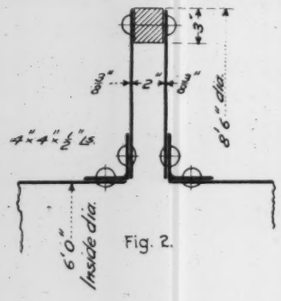


Fig. 2.

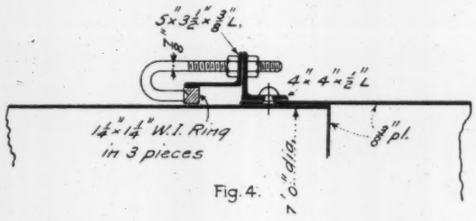


Fig. 4.

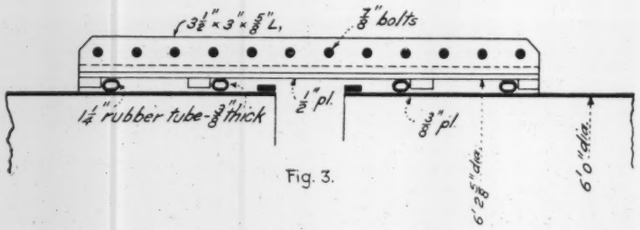


Fig. 3.

FIGS. 2, 3 AND 4. EXPANSION JOINTS FOR STEEL PENSTOCKS.

Between anchorages some means must be provided for taking up the expansion. This may be accomplished in a few cases by introducing bends of large radius. This is a very desirable construction when permitted by the location and topography of the site. More often, however, it is necessary to introduce some form of expansion joint, or slip joint, several styles of which are shown in Figs. 2, 3 and 4. Fig. 2 shows a type of expansion joint suited to short penstocks where the movement due to expansion is very slight. It has the advantage of requiring no packing and therefore needs only to be properly riveted and caulked to insure tightness. As will be seen it consists of two flat circular plates riveted to a spacing ring at the outer circumference and to angle iron rings on adjoining sections of the penstock at the inner circumference.

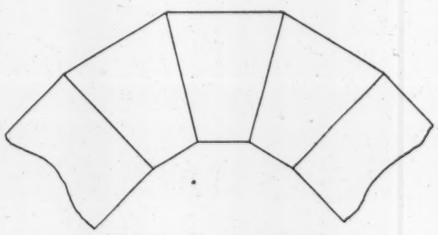


Fig. 5. Wrongly Designed.

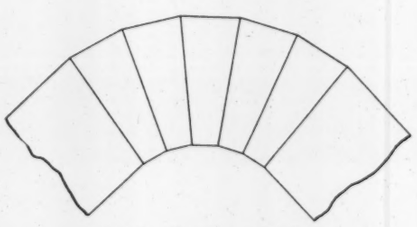


Fig. 6. Correctly Designed.

Figs. 5 and 6. Elbows for Steel Penstocks.

Fig. 3 consists of a sleeve encircling the penstock and made in two or more plates joined by angles bolted together. The packing consists of endless rings of rubber tubing which are held by the water pressure against rings riveted to the inside of the sleeve. It is a good plan to provide a few set screws in the sleeve so that it can be maintained equi-distant from the penstock all around. Fig. 4 is a type of joint which is easily packed, soft hemp or cotton packing serving very well with this type of joint. The ring which acts as a gland can be made in several pieces and the segments do not require to be fastened together in any way.

A very important, though seemingly small, part of the penstock is the air-vent. The writer knows of one case where its omission certainly resulted in the collapse of the penstock under the pressure of the air when the head-gates were closed. The air vent is usually a small vertical branch from the main penstock, open at the top and, of course, of a sufficient height to reach above the level of the head water. In northern latitudes this has the objection that the formation of ice in winter renders it useless. In such cases it is more desirable to provide a large well in the bulkhead just above the entrance to the penstock, the head-gate closing over an arched opening in the concrete wall between this well and the forebay. The well can be covered with a removable grating and thus can be more easily cleared of ice than a small vent-pipe.

Another important adjunct of the penstock is the stand-pipe, the office of which is to reduce water-hammer to a minimum. A properly located and proportioned stand-pipe is the best possible safeguard against bursting of the penstock under the tremendous pressures which may be produced by water-hammer, and it also is a great help toward good governing of the wheels. In a majority of designs probably, it has been customary to look upon the stand-pipe as a safety device whose great purpose was to relieve water-hammer. Surge pipes and surge tanks can be designed, however, to care for the excess and deficiency of water during surges resulting from operation of the gates or the governors. It is possible to replace the tall surge pipe by a closed surge tank where the effects of the former are obtained by air compression. The determination of the proper size and location of the stand-pipe is a complex subject which will not be taken up here, but the reader is referred to the excellent paper on this subject presented by Mr. Raymond D. Johnson before the American Society of Mechanical Engineers (June 25, 1908) which, with the discussion following it, forms a good treatise on the subject. The size having been determined, the thickness and weight may be found by the same methods as outlined above for the penstock. The stand-pipe preferably should be supported independently of the penstock on suitable steel or concrete supports, but the writer knows of a case where a stand-pipe nearly 60 ft. high was supported directly on the penstock, independent supports being impracticable. The body of the penstock was stiffened by heavy angles riveted on the outside and close to the stand-pipe. The stand-pipe was 4 ft. 6 ins. in diameter and the penstock 8 ft.

LAYING OUT PLATES.—The actual laying out of plates is hardly a matter within the scope of the present paper, but a few general remarks on the design of bends may be of practical use. In the first place, the designer should select as long a radius as practicable, not only for the sake of hydraulic efficiency but also for the greater ease of construction. The sharper the bend the closer together must the seams be in order to avoid too much flanging of the edges of the plates. The first seam in the bend must not be at the point of tangency, as it is so often shown by careless draftsmen, for the reason that the end of the tangent pipe, if cut square, will be a true circle, while the mating edge of the first section of the bend, being cut on an oblique angle, will be an ellipse. Hence the two edges will not match. It will be seen, from Figs. 5 and 6, that seams are in the planes of radii of curvature. An improperly designed elbow is shown in Fig. 5 and one properly designed in Fig. 6.

Reductions or enlargements of diameter should be as gradual as possible, both on account of hydraulic efficiency and for ease and economy of

construction. In the case of branches, however, good efficiency requires more expensive construction since branches carrying any considerable portion of the flow should be set at an oblique angle facing the stream. The higher the speed of water the more desirable and necessary is this construction since the tendency to set up eddy currents is greater.

Should the layout be such that the penstock cannot be completely drained by opening the wheel gates a small branch must be provided, with a suitable valve, at the low point.

ERECTION AND PAINTING.—The most suitable method of erection depends on so many conditions that it would be impossible adequately to discuss the subject within the limits of this paper. For instance it depends on the nature and accessibility of the site, size and weight of penstock, length of penstock, and a variety of other conditions. Small penstocks can be riveted up in the shop into sections the length of a railroad car, larger sizes, perhaps, may be shipped more economically in 10-ft. lengths standing on end, while the largest must be shipped knocked down and all the riveting done in the field. Compressed air, always a convenience where riveting is to be done, becomes practically a necessity when heavy plates and large rivets are used.

In the question of painting there is perhaps more variation in different specifications than in any other one particular. To the author's mind, unquestionably the plates are the better for a thorough cleaning before painting, which may be done best with a good sand-blast. This is to be followed immediately, according to some specifications, by a coat of linseed oil and this, after erection, with two good coats of some first-class metal-protective paint. The best paint is none too good for this work, since a penstock is exposed to unusually trying conditions and the expense and delay incident to repainting or repairs is often a serious matter. For that reason it is well for any designer, or any one who writes specifications for steel pipe lines, to keep in touch with every latest real advance in the protection of such structures from the effects of corrosion.

The Collection and Disposal of Refuse in the City of Boston, Mass.

The collection and disposal of the garbage, rubbish, ashes and other refuse of the city of Boston by contract, under a single contract, with disposal of the entire body of mixed refuse "in modern incinerators of the so-called English Destructor type," is recommended by a special commission in a report dated Jan. 31, 1910. For immediate construction a 300-ton destructor to be located in the Roxbury district, is suggested. A tentative plan for a combined refuse destructor and garbage reduction plant, submitted by a contractor a few months ago but subsequently withdrawn, is recommended for consideration in case it should be presented again.

The commission which made this report is the second which has dealt with the general subject. The first commission was appointed on Nov. 8, 1908. It submitted a detailed report in 1909, which gave an account of methods then used and advised that a contract be let for collection and for incineration of all wastes. The second commission, three of whose members were on the first one, was asked to carry the investigations somewhat farther, and to submit "suggestions as to the scope and form of" a contract. The membership of the second commission was: Francis R. Bangs, Chairman; a lawyer, trustee of large real estate interests in Boston, and a former member of the Board of Aldermen. X. H. Goodnough, M. Am. Soc. C. E., Chief Engineer of the Massachusetts State Board of Health. Arthur M. Huddell, representing the Central Labor Union. Prof. Wm. T. Sedgwick, Professor of Biology at the Massachusetts Institute of Technology. Frank L. Young, a Boston merchant and manufacturer. Guy C. Emerson, M. Am. Soc. C. E., Superintendent of Streets. John S. Hodgson was Secretary to the Commission.

The reasons for advising a single collection, with disposal by burning, in place of the present two-separation and three-separation system, with disposal of most of the garbage by reduction, disposal of a portion of the rubbish by sorting, sale and burning, and miscellaneous disposal of ashes and large quantities of rubbish, are stated in the second reports, as follows:

Sanitary Aspects of the Problem.

The fundamental considerations in the disposal of city wastes are those of public health, public comfort and public convenience. If these considerations did not exist the municipality might regard with comparative indifference the accumulation by individuals, families, manufacturers or tradesmen of ashes, garbage and combustible refuse. Such accumulations, however, not only block the public highways and otherwise interfere with the public comfort and convenience but are also liable to be or to become centers of infection in which disease may be diseminated throughout the community by individuals, by winds, by insects and possibly in other ways. They may also become centers of putrefaction or decay and the sources of disagreeable or disgusting odors. Garbage by its fermentation and puterfaction may become foul, and even ashes, so called, under the conditions of collection referred to in this report, are seldom free from suspicion, because garbage and dirt get mixed with ashes and hence make these only somewhat less objectionable than material more obviously contaminated.

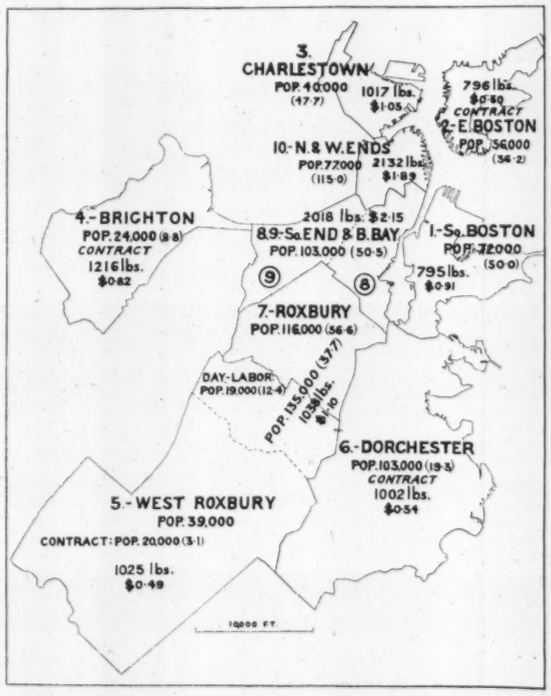


FIG. 1. BOSTON REFUSE COLLECTION AND DISPOSAL DISTRICTS AND STATISTICS.

(Populations are estimated means for year 1908, and are followed by average populations per acre. The pounds and dollars figures are weights and costs per capita for the year.)

"Separation," under whatever system of collection, is always more or less imperfect and incomplete. Some house or store dirt, for example, will find its way into receptacles intended only for papers or for garbage; some papers into receptacles for ashes and garbage; some garbage into receptacles intended only for papers or for ashes. And house dirt is peculiarly exposed to infection and is doubtless often really infected dirt. Garbage, which is in large part food or kitchen refuse, represents material that has been handled or mouthed and may have been infected even before it underwent such treatment. Hence it comes to pass that not even paper or ashes, as actually collected, can be regarded as certainly free from infection; while garbage must be recognized as being peculiarly exposed to it.

The sanitary aspects of the disposal problem are therefore not peculiar to any class of city wastes but fundamental to all, and if there were no other reason for the collection and disposal of these wastes by the municipality the sanitary reason would be all-sufficient.

There is, however, one class of ashes which is so little exposed to infection as to belong in a group by itself, and that is the ashes from factories, churches, schoolhouses and other large establishments into which food does not enter, or only to the slightest degree, as, for example, in the case of schoolhouses. It is a question, therefore, whether the municipality is bound for its own protection to collect and dispose of this sub-division of city waste, and it is plain that, if such necessity does not exist, the municipality may reasonably be free from a heavy financial burden which it now bears. A little reflection will show that while the municipality cannot safely neglect the collection and disposal of any of the wastes produced by families, it can and ought to be relieved of the burden of the collection of ashes from industrial, educational and manufacturing establishments. The boiler ashes produced by these, being practically free from all admixture of organic matters, are in nowise dangerous to the public health and ought to be removed by the producer, as would a mass of old bricks or mortar set free in making repairs to buildings.

In addition to boiler ashes, and more or less subject to the same considerations, there are certain kinds of trades rubbish, such as books and papers from book stores, news stands and publishing plants; boxes and papers from grocery stores; hay, straw, excelsior and other packing materials, and the like.

Turning now to the unsanitary aspects of the present system, with more particular regard to the inevitable admixture of garbage and other materials readily subject to infection, the deposit of so-called ashes and dirt upon inland dumps is highly objectionable from the sanitary point of view. Similar considerations apply to the disposal of ashes at sea, with the difference, in this case, that the nuisance and danger arising from floating matter are transferred to the territory of neighboring municipalities.

Another sanitary objection to the system of collection and disposal under the separation system is the larger number of hands which either necessarily or naturally come in contact with the refuse to be got rid of.

In short, from the sanitary point of view, any system of collection and disposal which involves separation is distinctly inferior to the simpler method of a single collection of mixed materials and the exposure of the combined mass to a high temperature under conditions designed to obviate nuisance at that stage. The advantages of this method of final disposal, known as incineration, are more fully set forth towards the close of this report.

Classification and Quantities of Wastes and Present Methods and Costs of Disposal.

Before quoting from the report under this head it may be noted that the commission estimates that the city is now paying $100,000 a year for collecting ashes and miscellaneous wastes from business blocks without legal authority to do so.

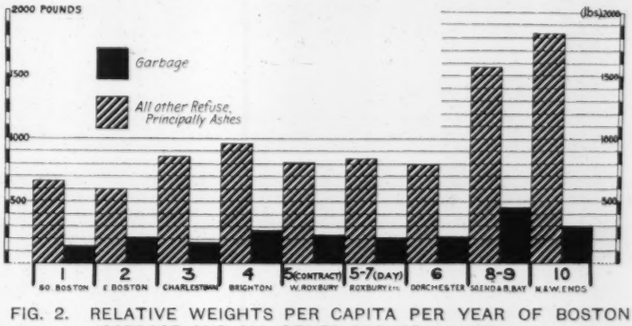


FIG. 2. RELATIVE WEIGHTS PER CAPITA PER YEAR OF BOSTON GARBAGE AND ALL OTHER REFUSE IN 1908.

The accompanying table shows the total and per capita quantities of different classes of refuse collected in various districts and in the whole city during the year ending Jan. 31, 1909.

Fig. 1 is a map showing the location of the various districts named in the table, together with some interesting quantity, cost and other data. Fig. 2 shows graphically the relative per capita per annum quantities of garbage as contrasted with all other refuse for the year 1908.

We quote further from the report as follows:

COLLECTION.—In general, collection in the suburban districts is made by contract, and in the more thickly settled and business districts by day labor. The day labor force consists of 607 men, with 260 horses for all purposes. The city maintains a shop, employing 38 mechanics, for the purpose of manufacturing and repairing equipment. The total tonnage collected by day labor for the year 1908 was 230,047, at a cost of $648,866, including disposal, or at the rate of $2.03 per ton.

In the suburban districts of East Boston, Dorchester, West Roxbury and Brighton all classes of refuse are collected by contract. The total amount of refuse collected in these districts for the year 1908 was 83,720 tons, and 133 men and 88 horses were employed by the contractors. The total cost was $92,389.23, including disposal, or at the rate of $1.10 per ton. This cost is doubtless lower than would be the case if the contractors were precluded from profiting by the feeding of garbage to swine, and there are other features of the department's contract work, notably the shorter hauls and the elimination of the charges for transportation to sea, tending to complicate any comparison with the cost of day labor.

Taking day labor and contract work together, it will be seen that a total of 403,767 tons, exclusive of market refuse received, was collected and disposed of, at a total cost of $741,254.94; that is, at the rate of $1.84 per ton.

DISPOSAL.—Of the 311,586 tons of ashes and house dirt collected during 1908, 87,000 tons, or 28%, were discharged upon the city scows at Fort Hill Wharf, on Atlantic Ave., and dumped at sea beyond the harbor limits. The remaining 244,586 tons were deposited upon dumps in various parts of the city.

Of the 78,615 tons of garbage, 67,454 tons were delivered to the New England Sanitary Product Co., and conveyed to the reduction works of the company at Spectacle Island. The remainder, amounting to 11,161 tons, or 14% of the total quantity collected, was disposed of by the suburban district contractors and used, to a greater or less extent, for the feeding of swine beyond the city limits.

Of the combustible waste and refuse, 12,050 tons were conveyed to the refuse destructor at Hecht's Wharf, Atlantic Ave., where the material is sorted, a part of it sold and the remainder burned, the ashes being discharged upon the dumping scows. The remaining combustible waste and refuse, amounting to 1,516 tons, was disposed of upon dumps.

The market wastes from the downtown section of the city, amounting in 1908 to 9,382 tons, and included in Table I, were discharged upon the dumping scows and disposed of at sea with the ashes and other refuse, the total carried to sea being thus 96,382 tons. Market wastes from other sections of the city were disposed of in connection with the house dirt and ashes.

Small quantities of refuse are disposed of by other means, which are negligible in considering the general question; for instance a number of hotels and restaurants dispose of their own garbage. Also, several persons have established routes for the collection of paper, which is understood to yield them some revenue.

Further information in regard to the distribution of the city's refuse, not including market waste, and the cost of its collection and disposal will be gathered from the two diagrams forming part of this report (Figs. 1 and 2).

The contract with the New England Sanitary Product Co., under which 86% of the total garbage collection of 1908 was disposed of, involves the treatment of the material by a reduction process, extracting some products of pecuniary value, the principal of which is grease. The city pays the company $52,400 per year and the contract expires on Jan. 1, 1912. [The average cost per to the city for the amount located by the company in 1908 was 78 cts.]

Having regard to the magnitude of the plant necessary to handle the work now being done by the company, it is absolutely necessary that the city take immediate measures to determine the methods to be adopted on the expiration of the contract.

The contract of the City Refuse Utilization Co., which expired on Sept. 15, 1908, and which has been renewed with the privilege of terminating it upon thirty days' notice from either party, is in some ways peculiar. The city pays an annual amount of $5,500 to the company [49 cts. per ton in 1908], and in addition pays $11,500 per year for Hecht's Wharf as a location for the plant, besides paying the taxes upon this property, the total cost of the plant to the city being thus in the neighborhood of $20,000 per year. The character of the waste delivered to the plant is very largely such that there is no authority under the ordinances for its collection. It is therefore probable that, under a strict interpretation of the ordinances, the city is paying in the neighborhood of $20,000 a year for the disposition of refuse to which it has no title and which it is not obliged or authorized to dispose of. In case it is found advisable to continue this method of collecting and disposing of this class of refuse, arrangements can doubtless be made which will insure greater advantage to the city than has hitherto been the case.

The report next deals with the general aspects of the reduction process of garbage disposal and then takes up the incineration of mixed refuse in much the same way. It notes that save for the recently-purchased plant at Cleveland, O., all garbage reduction works are owned and operated by private companies [but it overlooks the plant now under construction by Columbus, O.]. The report gives expression to the common idea that reduction works are always an actual nuisance, though not so as a matter of absolute necessity. It is stated that the Boston reduction works have been moved once on account of having been a nuisance and that although now located in a island in the harbor the plant still gives rise to complaints of unpleasant odors. For this reason, and on account of the difficulties of enforcing a separation of garbage from other refuse, the Commission favors incineration rather than reduction.

Another advantage of incineration mentioned in the report is based on the assumption that refuse destructors might be located in centers of heavy production of refuse, thus reducing the transportation charges. It is also stated that the mixed system of collection, made possible by incineration, would tend to reduce the odors from garbage in warm weather, through the mixing of ashes with the garbage.

The chief disadvantage of the proposed method of burning all wastes is the additional cost, which "with the best management" is placed at about 75 cts. per ton. It should be remembered, here, that ashes and other refuse in large quantities are got rid of by dumping.

As to the tentative offer, made last year, for a combined disposal plant, in which garbage would be reduced for the recovery of grease and fertilizer and all other wastes would be burned, the Commission considers that this would be practicable and might be advantageous, but only if both collection and disposal were done by contract. Municipal operation would be particularly questionable, the Commission thinks, because so many commercial operations are involved, which city governments cannot as a rule handle advantageously. A long-term contract would be necessary for such a combined disposal system.

It is interesting to note that the labor-union member of the Commission, while signing the report, does not agree with the recommendations for avoiding all day-labor work. We quote the majority and minority opinions on this subject, given at the conclusion of the report:

The majority of the members of the commission are of opinion that it would be to the advantage of the city in either case to do the work by contract and, if a suitable contractor can be found, that it would be better to let the entire work of collection and disposal for the whole city to one contractor. The reasons in favor of this view are briefly as follows:

They believe that the work can be done more cheaply by contract, as contractors have more control over their working forces than the city departments have over theirs. There is less chance for politics to enter in and more incentive to do the work economically. Especially, if a method of disposal is adopted in which there are products from the refuse to be sold, they believe that the city would be at a great disadvantage in disposing of such products as compared with a private concern. They also think it desirable that the city should escape a large investment in horses, carts and similar equipment, which are assets of fast depreciating value and susceptible of great waste and extravagance in their initial purchase if attended to by inexperienced or inefficient officials. There are other advantages of the contract system, as, for instance, that the more work that is let out by contract the less liability there is of having pensioners or incompetent or superannuated men on the city payrolls. Further, that it is an advantage to know just what the expense will be year by year, and not have the amount fluctuate violently according to the competence or incompetence of the head of a city department. They find, from the experience of the city of Boston, that work of this character has been done by contract for much less than the cost by day labor, and they are of opinion that, with competent supervision, the work can be as well done by contract as by day labor. The danger that a contractor will employ inefficient or low-grade and objectionable men or teams to collect refuse from the houses of citizens can, in the opinion of the majority of the commission, be readily overcome by suitable provisions in the contract. They feel that if the city officials having charge of the enforcement of the contract show any disposition to do their duty, there will be no difficulty in detecting the contractor in the violation of such provisions, because practically every citizen will be glad to complain of any inconvenience to which he may be put by the contractor or his men.

Mr. Huddell dissents from the other members of the commission in the foregoing recommendation that the work should be done by contract. He feels confident that the city would give better service than a contractor, because the city would employ men of a higher grade and citizens of Boston exclusively. He holds also, that the large saving shown in the Sanitary Division during the last year, over the expense incurred in the preceding one, shows that the work can be economically done under the supervision of city officials by day labor, if the control of the department having charge of the work is kept in competent and efficient hands. He therefore believes that the best solution would be to allow the work to continue in the hands of the city, but to see that such provisions are made, by suitable legislation or otherwise, as will insure an efficient administration of the Sanitary Division.

Improvements in the refuse collection and disposal service of Boston during the past two years are certified to by all five members of the Commission, except Mr. Emerson, under whose direction the work has been.

Definition or Description of City Wastes to be Removed at Public Expense.

The report includes a proposed ordinance stating what wastes shall be removed hereafter at public expense, as follows:

PROPOSED ORDINANCE.

"Be it enacted," etc.

"The Street Department shall remove and dispose of the following classes of refuse from houses and from housekeeping apartments or tenements, free of charge to the producers of such refuse and to the owners and occupants of such houses, apartments and tenements, viz.: Swill and kitchen garbage, dust and sweepings, ashes from fires used wholly or principally for heating or cooking, waste paper, cardboard, string, packing

TABLE I.—QUANTITIES OF REFUSE COLLECTED IN THE CITY OF BOSTON DURING THE YEAR ENDING JAN. 31, 1909.

Material.	Quantity. (tons of 2,000 pounds.)	Names, Numbers and Estimated Populations of Sanitary Districts. South Boston. 1 (72,000)	East Boston. 2 (56,000)	Charlestown. 3 (40,000)	Brighton. 4 (24,000)	West Roxbury. 5 (39,000)	Dorchester. 6 (103,000)	Roxbury. 7 (116,000)	South End and Back Bay. 8 and 9 (103,000)	North and West Ends. 10 (77,000)	Totals. (630,000)
Ashes	Total for year	23,379	16,490	17,025	11,465	22,049	40,697	41,735	73,506	65,240	311,586
	Average per day*	75	53	55	37	71	130	133	235	209	998
House offal	Total for year	4,920	5,806	3,317	3,125	5,409	10,909	10,556	22,903	11,580	78,615
	Average per day*	16	18	11	10	17	35	34	74	37	252
Waste and rubbish	Total for year	315	....	....	....	....	.....	580	7,403	5,268	13,566
	Average per day*	1	....	....	....	....	.....	2	24	17	44
Market refuse	Total for year	....	....	....	....	....	.....	.....	.....	9,382	9,382
	Average per day*	....	....	....	....	....	.....	.....	.....	30	30
Totals	Total for year	28,614	22,296	20,342	14,590	27,458	51,606	52,871	103,902	91,470	413,149
	Average per day*	92	71	66	47	88	165	169	333	293	1,324

*Six days per week, 312 days per year.

terial, sticks, wood, rags, waste leather and rubber, xes, barrels, broken furniture and other similar light combustible refuse; tins, bottles, jars, broken glass, oken crockery, bones, shells, waste or broken metal d all other similar heavy or incombustible refuse. But e department shall not so take any such refuse from tels, apartment hotels, restaurants, licensed lodging use nor from any other buildings whatever except ose first hereinbefore enumerated and except buildgs occupied by the city, and the department shall not take the refuse of manufacturing or mercantile siness, nor dead animals, manure, grass, garden fuse, leaves, plaster, building materials, earth or ones, except from premises occupied by the city, but he department shall take and dispose of any refuse pon payment by the producer thereof to the city of ch compensation as the Superintendent of Streets shall om time to time prescribe."

In view of the care bestowed upon the terms of the recommended contract, we reprint the committee's recommendation in full, which would be quite as useful in nearly all particulars to any other city than Boston:

Recommendations as to the Contents of any General Contract for the Collection and Disposal of Refuse.

(1) The scope of the contract should be clearly defined. The classes of refuse that shall be taken and that shall not be taken should be specified, as well as the classes of buildings from which refuse shall be taken, and the classes of buildings from which refuse shall not be taken, except on payment by the producers of the refuse. For this purpose the commission refers to the proposed ordinance, set forth [just above], as a desirable basis for such enumeration of the material to be taken and not to be taken under the contract; but the contract should also provide that the contractor shall remove other refuse upon payment to him of a fixed or of a maximum fee per load, barrel or other measure. The contract should further provide that the contactor shall receive at his transportation stations, and convey thence for disposal with the other refuse, such refuse as may be brought there by persons other than the contractor, and should fix a maximum charge per load, barrel or other measure, which may be made by the contractor for such receipt and disposal. This provision, however, should be modified to meet the actual conditions under which the contractor proposes to do his work, as, for instance, if he should have one transportation station for combustible refuse alone, he should not be obliged to receive at that station refuse of a different character which might interfere with his work.

(2) The contract should contain a provision that the city does not represent itself to be the owner of the refuse, and that failure on the part of the producers of refuse to allow the contractor to have it shall not make the city liable to the contractor, nor be held to justify the contractor's default in fulfilling any of the requirements of the contract.

(3) If the method to be employed by the contractor requires more than one separation, the contract should contain a provision that failure on the part of the householders, or others, to separate the refuse, from whatever cause arising, shall not be held to justify the contractor's default in fulfilling any of the requirements of the contract.

(4) The contract should provide that the system and appliances used by the contractor shall be such as will give at all times a satisfactory quality of work and results, and if it appear at any time that such quality is not given, the city may order the contractor to make such changes as will result in the desired standard of efficiency, and the contractor shall promptly conform to such order; but the failure of the city to make such order shall not be held to relieve the contractor from any of his obligations under the contract.

(5) The contract should contain a provision that the contractor shall employ competent workmen for their respective services and shall, when so required by the Superintendent of Streets, discharge any disorderly, insubordinate or incompetent employee. None but skilled workmen shall be employed on work requiring special qualifications. The contractor shall employ competent foremen in sufficient numbers to supervise the work. Housing and boarding accommodations provided by the contractor for his employees shall conform to the regulations of the city in regard to structural fitness, minimum air space per capita and maintenance in a sanitary condition. Facilities for bathing, including an ample supply of hot water, shall be furnished by the contractor for his workmen, and suitable regulations for insuring the cleaning of workmen engaged in specially dirty work, and the washing and drying of their clothes, shall be made and enforced by the contractor. The contractor's employees shall be provided by him with suitable uniforms of such distinctive character, approved by the Superintendent of Streets, as will enable the wearers to be readily identified. Sufficient changes of uniforms must be provided, so that the employees shall maintain a neat and satisfactory appearance at all times.

(6) The contract should provide that the carts and wagons used by the contractor shall be of patterns approved by the Superintendent of Streets, that they shall be kept neatly painted and properly cleaned and shall bear in legible characters conspicuously displayed, the name of the contractor and a distinctive number for each cart or wagon. None but metal vehicles shall be used for the collection of garbage. The horses used by the contractor shall be well fed, groomed and otherwise adequately cared for at all times. No draft horse weighing less than fourteen hundred pounds shall be used.

(7) The contract should specify the number of times a week that the various classes of refuse shall be removed from the premises of the producers of it, or should contain a provision that the Superintendent of Streets may regulate this matter from time to time according to the seasons, the needs of the various districts of the city, or other causes influencing the desirability of a more or less frequent collection.

(8) The contract should provide that the contractor may treat the refuse received by him in such manner as he may see fit, provided that such treatment shall be sanitary and inoffensive, and that the refuse shall be destroyed or rendered thoroughly harmless and unobjectionable. The necessary plants for these purposes may be located at Spectacle Island, or at any other place or places approved by the Superintendent of Streets; but the contractor will be held responsible for any damage arising from his operations in this, as in all other respects, and shall have no claim upon the city in the event of his having to find new locations for such plants or any of them. The contractor may use inland dumps for disposing of refuse free from manure, garbage, paper and putrescible or combustible matter. The condition of such dumps must be at all times satisfactory to the Superintendent of Streets, and no refuse shall be transported to dumps within the city unless their location has been approved by him. No floating material and no garbage, nor any solid refuse of garbage after being subjected to treatment, except thorough incineration at a high temperature, nor any offensive liquid, shall be dumped or discharged by the contractor into waters within the city, nor into Boston Harbor, nor into the waters within, *i. e.*, west of, a line drawn from Minot's Light to Egg Rock Light.

(9) If a general contract for the collection of garbage is made, it will probably be desirable to sell to the contractor the present equipment of the Sanitary Division, including horses, harnesses, carts, etc., and a provision for such purchase, together with the purchase price, should be included in the contract; provision should also be made in it for selling or letting to the contractor such of the city's stables and other buildings as are now used by the Sanitary Division, and which will no longer be necessary to the city if the contract is made. And the contract should set forth specifically and fully the terms of any such sale or lease.

(10) The contract should also provide that the city will furnish for the use of the contractor three city wharves, such wharves to be the only places used by the contractor for dumping refuse into scows, provided, however, that the city may at any time resume occupation of one or more of such wharves on substituting equivalent facilities, of which the Superintendent of Streets shall be the judge, for the contractor's operations, and the contractor shall have no claim against the city on account of such resumption or substitution. The terms upon which these wharves shall be furnished, as to rent, taxes, repairs, etc., are matter of bargain to be determined at the time the contract is made.

(11) The contract should provide that in case of emergencies, such as fire, flood, etc., the contractor may, without additional cost to the city, use such methods for collecting, removing and disposing of refuse as may be approved by the Superintendent of Streets, and for such time as he may specify; but if in any other case the contractor shall fail to collect, remove and dispose of the whole or any portion of the city refuse as required by the contract, the Superintendent of Streets may give notice thereof in writing to the contractor; and if such failure shall continue after such notice for more than forty-eight hours, the city, using any labor or materials and, at its option, the whole or any part of the equipment and plant of the contractor, may do the work which the contractor fails to do, and the city may deduct from any sums due or to become due to the contractor under the contract the amount expended by it in performing such work, on the certificate of the Superintendent of Streets, and such certificate shall be conclusive as to all facts stated therein. The provisions contained in this article are not to exclude other remedies for breach of this contract.

(12) In case of any difference of opinion between the contractor and the city, not affecting matters left in the contract to the decision of the Superintendent of Streets or expressly excluded from consideration, it should be provided that such difference shall be left to arbitration in the usual form, the arbitrators to be appointed in the usual manner, and the reasonable expense of any arbitration to be placed by the arbitrators upon both or either of the parties to the contract, as shall appear to the arbitrators to be just.

(13) There should be included in the contract a schedule of deductions in the nature of liquidated damages, which the Superintendent of Streets shall have power to order taken from the periodical payments to the contracter, in cases of small omissions and failures on his part to perform the contract to the satisfaction of such Superintendent. As for instance:

(1) Neglecting to remove refuse, $.... per house.

(2) Carts or wagons not covered, overloaded, not kept reasonably clean, or in need of painting or marking, $.... each.

(3) Garbage kept longer than .... hours before removal from wharf or other place of deposit, $.... per load.

(4) Refuse spilled and not immediately cleaned up, $.... per each case.

(5) Neglect to replace refuse receptacles, $.... per each case.

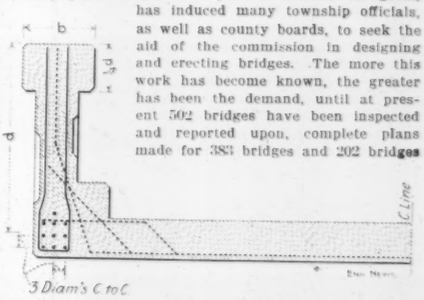
(6) Failure to wear the prescribed uniform, or wearing uniform in unsatisfactory condition, $.... per day per man.

Design and Cost of Reinforced-Concrete Highway Bridges.*

By A. N. JOHNSON.†

This paper presents some cost data of highway concrete bridges built in 1909 under the specifications and supervision of the Illinois Highway Commission. Under the law creating this commission, it can (upon request) give local officials advice concerning roads and bridges. The work is purely advisory and can be undertaken only at the invitation of the local officials, who may or may not accept the advice offered.

The inspections, plans, estimates, specifications, and supervision given to the work by the commission upon request are all without charge to the township or local community. The fact that in the past they have built so many poor bridges at a price oftentimes too great, has induced many township officials, as well as county boards, to seek the aid of the commission in designing and erecting bridges. The more this work has become known, the greater has been the demand, until at present 502 bridges have been inspected and reported upon, complete plans made for 383 bridges and 202 bridges



Half Cross-Section of Typical Design for Through-Girder Reinforced-Concrete Bridges; State Highway Commission, Illinois.

completed or under contract, of which 137 are of reinforced concrete.

Probably a majority of the bridge sites in Illinois have a low headway. Foundations usually must rest on earth; in many instances it becomes necessary to drive piles, in order to give sufficient bearing. It is exceptional that the rock approaches near enough to the surface to found the abutments on it. Therefore, it became necessary to adopt such a design as would give maximum clearance and waterway, and be adapted to an earth foundation. We developed a through girder concrete bridge having two girders to which the floor is hung; in this way we use a minimum of clearance and give a maximum waterway for a given distance between abutments.

This type of bridge has its limitations. A bridge supported by two girders to which the floor is hung is limited as to width of roadway for a given span and also as to length of span. It was found, however, that, where the roadway is not required to be over 18 or 20 ft. wide, this type of bridge proved economical up to spans of 40 to 60 ft., as compared with arches having the same area of waterway and designed to carry the same loads. While the tops of the girder bridges are heavier than would be required for arches, yet, owing to the fact that there is no horizontal thrust developed, the abutments do not need to be as extended or as heavy. There is, therefore, less concrete for the width of roadways named (taking the abutments and superstructure as a whole) in the through girder design than for arches, as above. In appearance the girder bridges are massive and well adapted to their apparent purpose, having in general a not unpleasing outline.

Perhaps the greatest advantage possessed by the girder type over the arch is the slight damage (if any) to the former in the event of uneven settlement of the abutments, such as is very apt to occur in many of the soil conditions encountered. Such displacement of the

*Abstract of a paper presented at the annual meeting of the Illinois Society of Engineers and Surveyors, at Cairo, Ill., Jan. 26, 28, 1910.

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abutments of an arch would be extremely hazardous to its stability.

DESIGN.—The formulas used in the design of these bridges have been reduced from the general formulas developed by Prof. A. N. Talbot and others. The form in which we use them is that most convenient for bridge design. The first factor to determine is the stress to be allowed in the concrete and the steel, which, when once fixed, determines the percentage of steel reinforcement. The compression allowed in the concrete is 750 lbs. per sq. in. for concrete 60 days old, with a corresponding stress in the steel in tension of 16,000 lbs. per sq. in. This corresponds to practically 1% reinforcement.

To compute the dimensions of a girder to withstand a given bending moment (M) where (b) is the breadth, and (d) the depth from the top of the beam to the center of gravity of the steel (using the above stresses) we will have

$$M = 0.853 \times 16{,}000\ bd^2 \times 0.01$$

As we usually assume b and desire d, this reduces to the simple form

$$d = \sqrt{\frac{M}{136\ b}}$$

For computing the depth of T-beams (see accompanying cut), the width of the flange (b) is assumed, and the depth is then computed by the above formula, but always making the depth of the flange not less than 25% of the value found for (d).

To provide against diagonal tension in the webs of beams, U stirrups are used where the shear in the concrete exceeds 30 lbs. per sq. in. The amount of steel to be provided is found thus: Let (V) be the total shear in a given section of the beam. The steel (stressed at 16,000 lbs.) necessary to carry 0.6 V is distributed along the beam for a distance equal to the height of the beam ($= d$). For example, if V = 200,000 lbs., 0.6 V = 120,000 lbs., which would require 12.5 sq. ins. of steel. If the value (d) of the beam is 60 ins. there is required 12.5 sq. ins. of steel for 60 ins., or 0.208 sq. ins. of steel per inch of girder. A U-shaped stirrup of ¾-in. square rod would have in both legs 1.12 sq. ins., which divided by 0.208 will give the spacing for the stirrups. In this case it would be about 5 ins. for the first 60 ins. along the beam. In the next section a new value for the shear would be computed, and the rods and stirrups spaced accordingly, as we usually compute the shear for sections which are arbitrarily spaced along the beam equal to its depth (d).

The thickness of the web of the T-beams should be investigated for horizontal shear. Usually, however, the governing factor in determining the thickness of the web is the space required for the reinforcing rods.

The dead loads for all concrete bridges are taken thus: Concrete at 144 lbs. per cu. ft., crushed stone at 90 lbs., and earth at 100 lbs. per cu. ft. Live loads are uniform 125 lbs. per sq. ft. and concentrated live load of 24 tons distributed on two axles 10 ft. apart (8 tons on the front and 16 tons on the rear axle). The load is taken as applied over a width of 12 ft. The moment for both uniform and concentrated live loads is computed, and the greater combined with the dead load moment to determine the girder and floor dimensions.

CONCRETE.—The character of the concrete is a factor governing the cost. The specifications provide for a 1:2½:4 mixture for reinforced work. This was determined upon after considerable experience with a 1:2½:5 mixture, which did not secure an altogether satisfactory finish. As much of the surface of the concrete is exposed in bridges, a smooth, close-grained surface is particularly desirable. If a smooth finish is to be secured, (1) the forms must be carefully made and kept true to alinement, and (2) the concrete must contain sufficient mortar to more than fill all voids in the aggregate. This is not secured satisfactorily when the proportion of mortar to the aggregate is 50%, as in a 1:2:4, 1:2½:5, or 1:3:6 concrete. The specifications were therefore changed so that the proportion of mortar to the aggregate varies with different classes of concrete, according to the purpose for which it is to be used.

In reinforced work, we have endeavored to use a concrete which will have a volume of mortar about equal to 60% of the volume of the aggregate. Such an amount of mortar is not necessary where the concrete is placed in large masses, but in most reinforced work the concrete must be placed around the reinforcing rods and molded closely against the forms, which are not a great distance apart. Under these conditions, if honeycombed effect is to be avoided with the workmanship ordinarily secured, concrete with more than 50% mortar should be used. In gravel concrete, the amount of cement to be used is proportioned according to the amount of sand. The amount of aggregate that may then be allowed depends upon the voids in the aggregate, mortar being supplied to at least 60% of the voids for use in reinforced work. Aggregate for this class of construction moreover should not exceed 1-in. in size if it is to be satisfactorily placed about the reinforcement.

The specifications do not call for any particular kind of reinforcement, other than it must have some means of rigid mechanical bond at frequent intervals. In nearly all the work so far done square, twisted rods have been used.

FORMS.—The specifications and drawings provide for rigid forms. Particular attention is paid to the bents supporting the structure during construction. It is evident that great care must be exercised to prevent any settlement of the girders while the concrete is hardening, when it is borne in mind that, for spans of 40 to 60 ft. the girders and floor weigh 6 to 7 tons per running foot. The plans for the longer spans require that the bents supporting the forms shall rest on piles firmly embedded, unless the stream bed is of such a character to make this unnecessary. But such a condition is the exception. In a number of instances the contractor has put in concrete footings flush with the bottom of the stream bed to support the bents.

COST.—The cost data given in the accompanying table were collected by the resident inspectors in the employ of the State Highway Commission. They kept a daily record of all labor for each portion of the work, together with the quantity and cost of all materials. The cost of materials was generally obtained from the bills, and the prices secured from the contractors. The amounts given, therefore, do not contain any allowance for the office maintenance of a contractor's organization, no traveling expenses of the contractor, nor any allowance for profit. Also, in the cost for forms, deduction has been made for the actual salvage on all lumber; but as most of the work was in the country there was little opportunity for the contractor to dispose of this material to advantage. All the work noted was done during 1909; other work was done but the data were insufficient for inclusion in the table.

In a number of instances the actual cost to the contractor was greater than his contract price. It is well to consider what were some of the causes for such results. Incompetency on the part of the foreman is probably the most usual cause either of direct loss to the contractor, or at least a great reduction in the profit reasonably to be expected. The loss usually occurred in the foundation portion of the work. Sufficient precaution would not be taken to prevent caving, with the result that a large amount of extra material would be shoveled from the bottom of the trench to the top. Good sheeting well braced is usually required.

In a few instances, increased cost to the contractor was occasioned by doing part of the work twice, owing to the use at first of poor materials which had to be replaced. In some instances foremen were found who could scarcely read the plans, and (except for the assistance of the inspector) would have had a sorry time of it. Others had no control over their men, who loafed or worked much as they pleased. It is evident that under such conditions no profits could be expected. Probably all the contractors intended to send competent men, and possibly sent as good as they could get. But when good men are scarce, it is not to be expected that they will be attracted by a poor salary. An adequate wage will usually secure competent foremen.

Money was also lost on some jobs through ignorance on the part of the contractor in making his bid. In a few cases contracts were taken at prices 30% and 40% below the estimate. The bids from experienced contractors at the same letting would be for a rational sum. There should be some way by which a bid manifestly too low (for bridges or other public works) could be rejected as readily as bids that are too high. To accept a bid that is too low is unfair to the reasonable bidders, takes unfair advantage of the contractor making the low bid, and (by putting a premium on poor work) is unfair to the taxpayers.

The cost data should afford some guide in making bids on similar work. Owing to the great variance in conditions it is impossible to state what price should be secured for reinforced-concrete bridges to insure in a given instance a reasonable profit. It will be noticed that the cost per cu. yd. of concrete varied as follows:

Cement	$2.35	to $1.25
Stone	3.23	" 1.30
Sand (excluding gravel concrete)	1.47	" .32
Gravel	2.43	" .70
Forms	3.95	" .83
Placing steel	3.10	" .80
Mixing and placing concrete	2.72	" .72
Excavation	3.91	" .21
Total	$17.51	" $6.54

From such a wide variation, it becomes apparent that averages will help but little to estimate the cost of a particular job. One of the most uncertain features of this class of work is the cost of the excavation. It would probably be a more exact method of distribution if the cost per cu. yd. for the foundation were given

COST DATA OF REINFROCED-CONCRETE BRIDGES BUILT IN 1909.

Name.	Clear Opening, ft.	Roadway, ft.	Height of Abutments, ft.	Substructure: Concrete, cu. yds.	Substructure: Steel, lbs.	Superstructure: Concrete, cu. yds.	Superstructure: Steel, lbs.	Total concrete cu. yds.	Total steel, lbs.	Cost per cu. yd.: Cement.	Stone.	Sand.	Gravel.	Forms.	Steel in place.	Mixing placing concrete.	Excavation per cu. yd. concrete.	Total cost per cu. yd. concrete.
Hamel	7	18	7	22.71	850	6.91	670	29.62	1,520	$1.35	$2.44	$0.61	....	$1.50	$1.16	$1.61	$1.28	$9.95
Hackle*	8	20	14	61.74	2,927	7.42	741	69.16	3,668	1.81	0.77	0.80	....	1.71	0.81	1.56	0.41	7.87
Erosting	10	16	14	46.55	1,652	11.45	1,041	58.00	2,693	1.51	....	1.06	$2.05	1.59	0.80	1.16	1.16	9.33
Stahlhurtt	12	14	..	....	....	....	....	16.00	1,800	1.30	3.23	0.32	....	2.07	2.41	0.95	....	10.28
Geo. Schreiner	12	16	9.5	35.60	1,290	11.85	1,223	47.45	2,513	1.85	....	....	1.19	2.16	1.53	1.23	1.09	9.05
Cronkhite	12	18	13.5	52.87	1,928	17.13	1,554	70.00	3,480	1.46	....	0.86	1.72	2.39	0.84	1.46	2.16	10.89
West Avery	13	16	8.5	37.60	....	34.20	4,120	71.80	4,120	2.25	....	....	1.00	1.70	1.28	0.80	1.09	8.12
Carr	14	16	12	33.28	1,027	13.33	1,924	46.59	2,951	1.74	2.61	1.10	....	1.37	1.13	1.77	0.50	10.22
Thompson	14	16	15	27.07	724	14.93	1,647	42.00	2,371	2.05	2.71	1.46	....	2.50	1.26	1.81	1.70	13.50
Town Line	14	19	8.5	34.74	1,893	17.38	1,938	54.85	3,830	1.34	3.06	0.75	....	1.01	1.72	0.84	1.06	9.80
Joe Haffer	14	16	9	23.74	700	14.93	1,647	38.67	2,347	1.56	1.64	0.72	....	1.44	1.44	2.05	1.00	9.85
Feldman	14	16	22	139.00	10,633	15.44	1,688	154.44	12,321	1.48	1.99	0.65	....	2.38	1.80	1.95	3.91	14.25
Phillips	14	16	11	29.82	790	13.31	1,926	43.13	2,716	1.74	2.78	1.23	....	1.58	1.24	1.93	0.81	11.31
Funk	14	16	9	26.96	879	14.93	1,647	41.89	2,526	1.63	1.66	0.61	....	2.16	1.43	1.16	1.07	9.72
Derickson	16	16	12	38.84	1,400	21.28	2,454	60.12	3,854	1.56	2.45	1.09	....	2.82	1.51	1.60	3.49	14.52
John Lawson	16	16	11	37.52	1,546	21.28	2,454	58.80	4,000	1.61	2.50	1.11	....	2.47	1.25	1.09	1.69	11.72
Stillwell	16	16	7.5	30.35	546	21.28	2,454	51.63	3,000	1.30	1.30	0.35	....	0.98	1.34	0.83	0.43	6.54
Culvert No. 1-6	17-12	..	..	....	....	....	....	48.37	6,307	1.72	....	0.73	1.83	1.36	2.64	0.98	0.47	9.73
Scotts	18	16	12.5	....	....	....	....	84.25	6,050	1.74	1.92	0.29	1.20	2.20	1.44	1.50	0.95	11.24
Edw Peterson	20	16	15	92.21	1,845	25.12	3,910	117.33	5,755	1.44	....	....	0.85	1.36	1.04	1.36	3.30	9.35
Lamb	20	16	13	56.79	1,428	25.12	3,910	81.91	5,338	1.87	0.88	0.40	0.88	1.74	1.37	1.27	1.45	9.86
Fuller	20	16	13	60.05	1,955	25.12	3,910	85.17	5,865	1.68	1.75	0.28	0.70	1.51	1.57	1.16	1.18	9.83
Dog Bridge	20	16	18	91.68	4,325	25.12	3,910	116.80	8,235	2.24	....	....	0.96	1.37	1.52	0.90	1.33	8.32
Lillis Creek	20	16	15.5	64.97	2,760	25.12	3,910	90.09	6,670	2.20	1.93	0.05	2.42	3.95	1.61	2.72	2.63	17.51
Philips	20	16	14.5	39.55	1,501	25.12	3,910	64.67	5,411	1.25	....	....	1.96	0.83	1.73	0.86	0.59	7.22
Sornburger	22	16	14	60.35	2,484	30.89	5,006	91.24	7,490	1.96	....	....	1.65	2.37	2.24	1.07	1.00	10.29
Creamery Cr.	24	16	8.5	32.10	1,194	30.89	5,006	62.99	6,200	2.31	....	....	1.91	1.97	1.95	0.72	1.52	10.38
White	25	16	11.5	38.35	1,355	26.18	5,416	64.53	6,771	1.62	0.49	....	1.65	2.72	2.48	2.07	1.67	12.70
Slough	25	16	7	60.12	1,936	26.18	5,416	86.30	7,352	1.45	2.12	0.94	....	2.31	2.75	0.90	0.21	10.68
McCouhey	25	14	13	44.62	1,789	24.20	5,085	68.82	6,884	1.87	2.97	1.47	....	2.57	1.90	1.14	1.13	12.05
Drl. Stassen	30	16	11	51.62	1,849	41.61	6,788	93.23	8,635	1.43	1.83	1.24	....	1.84	2.43	1.76	1.85	12.38
McNair	34	16	13	59.30	2,290	62.70	11,044	122.00	13,334	1.76	....	....	1.43	2.25	2.08	0.96	1.12	9.60
Schoeber	35	16	15	71.40	2,756	52.40	8,956	123.80	11,712	1.90	1.45	0.14	0.72	1.34	2.23	1.02	0.73	9.33
Roper	35	16	10	57.40	2,536	52.40	8,956	109.80	11,492	1.85	0.90	1.41	2.06	1.41	2.39	1.44	1.64	13.10
Stockland	50	16	12	71.60	2,213	63.60	13,784	135.20	15,997	1.47	1.49	0.47	....	2.60	3.10	2.01	2.57	13.71
Cligett	50	16	16	64.23	2,271	62.35	10,925	126.58	13,196	1.70	....	0.70	2.43	2.15	2.01	1.55	2.56	13.10
Boyd	50	16	15	73.75	2,328	65.00	14,172	138.75	16,500	2.35	....	....	1.60	3.24	2.32	1.53	2.02	13.08
Mud Creek	60	16	16	109.00	3,620	97.07	20,338	206.07	23,958	1.31	1.50	1.11	....	1.62	2.43	1.14	2.33	11.43

*Stone furnished free to contractor, except freight and hauling.

parately from the superstructure, charging all of the excavation against the concrete going into the foundation. This, however, was impossible from the data at hand. But the amount of concrete in each portion of the structure is given, which will assist in determining the proper distribution of the cost.

In general it may be said that (unless materials were exceptionally near at hand and obtained consequently at much lower cost than usual) there has been little profit to the contractor in this class of work at a price much less than $10 to $12 per cu. yd. It does not follow, however, that all of the work let at a less figure has been at a loss to the contractor, or that all jobs let at a higher figure have been at a profit. Some of the work let at a good figure was so badly managed as to put all the profits and cause an actual loss to the contractor. As the data here given include work both well and badly managed, this fact should be borne in mind in attempting to draw exact conclusions. But it is believed that these data, if used with judgment, should be of considerable help to engineers and contractors in making estimates on similar work.

The Greater Pittsburg Sewerage and Sewage Purification Orders.

There bids fair to be a metropolitan sewerage and sewage purification district for the city of Pittsburg, Pa., and a number of near-by boroughs and townships. Already some preliminary investigations looking to joint action have been made, and orders have been issued to the several municipalities to submit plans for sewage treatment to the State Department of Health. The most notable of these orders, three in number, were placed in the hands of the mayor of Pittsburg on Jan. 31, 1910. Taken together, they cover the whole of the present city of Pittsburg (which now includes the old city of Allegheny and other annexed territory). In addition, they strongly suggest or urge that a number of outlying municipalities be included.

We have called the documents orders, but technically they are permits, with attached conditions which have the effect of orders. Each order or permit resulted from an application by the city authorities of Pittsburg for permission to make extensions to the sewerage system of Pittsburg. These applications have been made a convenient basis for insisting on the formulation of plans for a complete system of trunk sewers and of sewage purification works for the city of Pittsburg.

The city is given until Dec. 1, 1911, to prepare and submit plans for the approval of the State Department of Health, and is given assurance of an extension of time, if that becomes necessary, provided due diligence is shown in attempting to comply with the orders.

We are indebted to Mr. F. Herbert Snow, M. Am. Soc. C. E., Chief Engineer of the Pennsylvania State Department of Health for the following general statement of the reasons for issuing these orders and for seeking joint action on the part of the several communities:

In the Greater Pittsburg district there are about two score of individual municipalities operating under the borough form of government whose water-supply problem is more or less a common one, as well as their sewage disposal problem. The topography is extremely rugged, the slopes precipitous and the valleys of the streams and ravines are narrow. The land bordering the Ohio River and the Monongahela and Allegheny rivers is the most valuable land. It has been acquired and is used for industrial purposes. So also have most of the lands been occupied in the valleys of the tributary streams in the district. The rivers and natural water courses receive the outflow of all sewers. Consequently there are many local nuisances. The water-supplies are either drawn from the ground or they are taken from the streams and the water is filtered. The principal exception is that of the North Side, formerly Allegheny City, where raw Allegheny River water will be furnished the consumers as in the past until the projected extensions to the city water-works system are completed.

In 1905, when the new State Department of Health was established, and Dr. Samuel G. Dixon assumed the duties of Commissioner, a study of the sewerage and water-works systems of the municipalities in the district was begun and from time to time decrees were issued until now most of the towns have been ordered to prepare comprehensive plans for sewerage systems for their entire respective territories and for some other method of disposal of the sewage than at present prevails. Some of the towns are so grouped with respect to position and topography that joint intercepting sewers are evidently demanded. The economy and efficiency of main sewerage districts comprising several boroughs has been pointed out in the decrees of the Commissioner. It has come to be generally recognized and accepted as a rational conclusion that the policy of the State Department of Health as declared by the Governor Attorney General and the Commissioner of Health in the several decrees for a main drainage district that shall comprehend the so-called Greater Pittsburg district, is a conclusive policy and that, therefore, there remains only the problem of working it out along practical lines. Hon. William A. Magee, Mayor of Pittsburg, has firmly grasped the situation and has already accomplished much in the way of water-works extensions, road building and improved transportation whose benefits will be shared alike by the citizens of Pittsburg and the citizens of the outlying towns. The decrees issued by Dr. Dixon to the city of Pittsburg relative to sewerage in furtherance of the State's policy for the district are not in opposition to but coincide with Pittsburg's interest and the policy of Mayor Magee.

It is plain common sense that sewers should be built in conformity with a plan for sewers for the entire community, nevertheless it is often the case that individual sewers are built regardless of such general plan and later such sewers may be abandoned or require rebuilding. The prevalent idea in the State Department of Health decrees is the compulsory adoption of a definite and comprehensive plan by the municipality and following this adoption the building from time to time, as necessity may require, sewers in conformity with this plan. And since there are few favorable points for the erection of sewage disposal works in the Greater Pittsburg District, or for the discharge of raw or partially treated sewage into the streams, it follows in consequence, as fully set forth in the decree of the State Department of Health to Pittsburg relative to the Saw Mill Run Drainage District and the Nine Mile Run Drainage District, and others, that a comprehensive sewerage plan cannot be studied and wisely settled without also studying the sewage disposal problem. Since Pittsburg is rapidly extending its territory by annexation and it would appear to be a matter of a decade or so before the city territory will comprise most of the outlying towns, the State authorities have concluded that the city, in studying its own sewerage problem, should include the area likely to become a part of the city in the future.

The engineering work for the State has been done by the writer; that for the city has been done by Mr. N. S. Sprague, Assoc. M. Am. Soc. C. E., Chief of the Bureau of Construction of Pittsburg. Mr. Allen Hazen, M. Am. Soc. C. E., of New York City, has been engaged by the city to act as consulting engineer.

Of the three orders issued one covers that part of Pittsburg having outlet sewers discharging into the Allegheny, Monongahela and Ohio rivers, while the other two cover smaller but important areas whose sewers now terminate in Nine Mile or Saw Mill rivers.

The Main District.

The first of these orders, as we have arranged them, devotes considerable attention to floods and their relation to the sewerage system, but contains few definite suggestions beyond the need of giving careful attention to flood effects in designing sewerage improvements. We refer to this part of the report to show how thoroughgoing the orders are.

The order next considers each of the present sewer outlets and the various minor drainage districts of the former cities of Pittsburg and Allegheny and of some outlying districts. It then proceeds with a general discussion. This we quote, calling particular attention to the account of a remarkable outbreak of gastro-enteritis and typhoid fever given in our quotation:

Discussion.

That public health is prejudiced by the drawing from sewage-polluted streams for sources of drinking water has been thoroughly demonstrated. The towns located on the banks of the Ohio River in Pennsylvania below Pittsburg, the population and source of water-supply are given in the accompanying table.

Seventy thousand people are now supplied with water by apparatus which is flooded all or a part of the time by sewage-polluted water, or which may be reached by such water and be the means of carrying into the homes of the water consumers a poison capable, under favorable circumstances, of producing sickness and death.

Some of the driven-well piping is more easily reached by the sewage water of the river than other piping. Breaks or leaks in pipe joints are liable to occur.

In some instances raw river water is supplied to the consumers. Where the water is taken in through filter cribs located in the bed of the river there is an element of purification which throws the consumer off his guard. Any serious accident to the filter crib would mean the introduction of sewage poison into the water-works system and the innocent would therefore be caught unawares. Even where the most perfect type of modern apparatus is built and operated with scientific attention, where every facility is afforded to regulate and control the treatment plant, none too high a degree of efficiency is obtained, and most sure it is that the crude filter, placed where it cannot be gotten at and repaired, falls short of the demands of public health where human life is placed in jeopardy.

Even the best filter plant is liable to break down. It is conceded by authorities that the interests of the public health demand that not only polluted waters should be filtered if used as a source of supply to the public, but the pollution of these waters in the first instance should be kept down to a minimum.

As the accompanying table shows, the towns located on the banks of the Ohio River in Pennsylvania below Pittsburg having water-works, with one exception only, rely on the Ohio River for drinking water. The district is a flourishing one and as these new towns increase in population, which they are bound to do, the importance of conserving the purity of the Ohio River for the protection of public health will relatively increase. It is to be regretted that foresight concerning this important resource, next in importance to that of the food supply, had not received earlier attention. However, it is not too late to effect a remedy.

An Outbreak of Gastro-Enteritis Followed by Typhoid Fever.

A vivid illustration of the danger spoken of was afforded by the outbreak of an epidemic of gastro-enteritis followed by typhoid fever during January of the current year, in the district supplied by the Ohio Valley Water Company. This corporation unthinkingly mixed a quantity of raw river water with its ordinary supply of well water and pumped it into the distributing system, whereupon there immediately followed within a few hours an outbreak of violent stomach disorder, to-

POPULATION AND WATER-SUPPLY OF PENNSYLVA NIA TOWNS ON OHIO RIVER BELOW PITTSBURG.

No.	Municipality.	River bank north or south.	Approx. Dist. below city point, miles.	Population, est.	Water-works Ownership. Company or Town.	Source of Supply.	
1.	Esplen	S.	2	1,000	Monongahela W. Co.	Ohio River.	Driven wells at river bank.
2.	McKees Rocks	S.	3	10,000	Monongahela W. Co.	Ohio River.	Driven wells at river bank.
					Ohio Valley W. Co.	Ohio River.	Driven wells at river bank.
3.	Bellevue	N.	4	8,300	Ohio Valley W. Co.	Ohio River.	Driven wells at river bank.
4.	Avalon	N.	5	5,000	Ohio Valley W. Co.	Ohio River.	Driven wells at river bank.
5.	Ben Avon	N.	6	2,000	Ohio Valley W. Co.	Ohio River.	Driven wells at river bank.
6.	Emeworth	N.	7	2,000	Ohio Valley W. Co.	Ohio River.	Driven wells at river bank.
7.	Glenfield	N.	8.5	(1,000)	No Water Works.	System.	
8.	Coraopolis	S.	10	6,000	Coraopolis.	Ohio River.	Filter cribs.
9.	Hayesville	N.	10	300	Hayesville W. Co.	Hayesville Run.	
10.	Osborne	N.	11	500	Sewickley.	Ohio River.	Filter cribs.
11.	Sewickley	N.	12	4,500	Sewickley.	Ohio River.	Filter cribs.
12.	Edgeworth	N.	13	1,400	Edgeworth W. Co.	Ohio River.	Filter cribs.
13.	Leetsdale	N.	14.5	2,300	Edgeworth W. Co.	Ohio River.	Filter cribs.
14.	Ambridge	N.	16	5,000	Harmony W. Co.	Ohio River.	Driven wells at river bank.
					Ambridge W. Co.	Ohio River.	Driven wells at river bank.
15.	Economy Vil.	N.	17	500	Harmony W. Co.	Ohio River.	Driven wells at river bank.
					Ambridge W. Co.	Ohio River.	Driven wells at river bank.
16.	Woodlawn Vil.	S.	18.5	2,500	Woodlawn W. Co.	Ohio River.	Driven wells at river bank.
17.	Baden	N.	20	500	Baden.	Ohio River.	Driven wells at river bank.
18.	Aliquippa	S.	20	1,000	Aliquippa.	Ohio River.	Driven wells at river bank.
19.	Conway	N.	20.5	1,000	Beaver Valley W. Co.	Ohio River.	Raw.
20.	Freedom	N.	23	3,000	Beaver Valley W. Co.	Ohio River.	Raw.
21.	Rochester	N.	25	6,000	Valley W. Co.	Ohio River.	Raw, Beaver River filtered.
22.	Monaca	S.	25	3,500	Monaca.	Ohio River.	Filter cribs.
23.	Beaver	N.	26	4,000	Beaver.	Ohio River.	Driven wells at river bank.
24.	Industry Vil.	N.	33	(200)	No Water Works.	System.	
25.	Glasgow	N.	38	(300)	No Water Works.	System.	
26.	Georgetown	S.	38	(200)	No Water Works.	System.	
				70,300	Supplied with water.		

talling 3,706 cases and followed by 63 cases of typhoid fever. In this district, on the north bank of the river and extending westward from Allegheny City, are the boroughs of Bellevue, Avalon, Ben Avon and Emsworth. North of Bellevue in Ross Township is Westview borough, which, together with the township and the above mentioned boroughs comprise the northern water district of the company.

On the south side of the Ohio opposite Bellevue is a thickly populated section of Stowe Township. On the eastern boundary of this township is the borough of McKees Rocks. McKees Rocks and Stowe Township form the southern water district of the company.

At the present time the Ohio Valley Water Co. furnishes water to 35,000 people.

On account of the elevation of the north district and its accessibility to Pittsburg, it has been rapidly developed for residential purposes by the business men of Pittsburg. In 1900 the population was 10,000. At the present time the population is estimated at 21,500. There is room for expansion and it would not be surprising if the territory would again double itself in population within ten years.

The southern district is chiefly an industrial and railroad community. The inhabitants are mainly employed in the various mills. The growth of this section has also been rapid. In 1890 it was 9,200 and at the present time it is estimated at 18,000.

Between these two water-main districts there are several islands located in the center of the Ohio River. The largest is Neville Island. It is five miles long and a third of a mile wide and most of it is above high water. On it are located several steel mills and at the upper end is the main pumping station of the Ohio Valley Water Co.

Immediately above Neville Island and separated therefrom by a narrow channel of the river, is Davis Island, and at the west end of Davis Island is located the Davis Island dam, hereinbefore mentioned. This structure extends from the island across the river to the north bank and is collapsible. It is designed to keep a normal stage of water in the river 9 ft. deep during the dry weather season and is lowered during high water. From the west end of Davis Island to Neville Island and from the east end of Davis Island to the southern bank of the river there is a concrete dam which prevents the water from leaving the main channel of the river.

The Ohio Valley Water Co. supplies on an average of 3,000,000 gals. of water per day. Practically every one in the northern water district is supplied by the water company. It is estimated that the number of consumers in this territory is 21,500 people. In the southern water district the Monongahela Water Co. supplies water from the Esplen pumping station to the borough of McKees Rocks, so that there is competition there. However, the Ohio Valley Water Co. furnishes the majority of the people. It has 10,500 consumers in the territory.

The supply is taken from a system of drilled wells located in the river bottom immediately north of the east end of Neville Island and just below the Davis Island dam. There are 12 6-in. wells and 6 8-in. wells driven to a depth of 27 ft. below the river bottom, all connected up by a suction line to the low-service pumps in the station. There are also 11 12-in. wells sunk in the sand bar located 200 ft. out in the river and having an independent suction to the low-service pumps. The piping of these wells is all below low-water mark.

At the pumping station there is a 20-ft. well back 50 ft. from the river bank, whose bottom is possibly 20 ft. below low water, from which water is pumped into a receiving basin adjacent to the pump house and located above flood level. Out of this basin the water is pumped into the towns. Off of the force main extending through the northern district to a masonry reservoir holding 1,700,000 gals. and located in Bellevue, several lateral feeders branch, so that the reservoir acts as an equalizer as well as storage basin.

Ross Township and Westview borough are supplied by an auxiliary pumping plant located at the Bellevue reservoir. The force main delivers water to the distributing pipe and to a stand-pipe in said borough.

There is a masonry reservoir in Stowe Township, capacity 6,000,000 gals. The force main leading to it is direct connected to pipes in the streets so that the consumers get water partly by direct pumpage and partly by storage in the reservoir.

Typhoid fever has been prevalent in the water company's district for many years. It has, however, not been ascribed to the supply of the company. Analyses of the water made from time to time have shown an exceptionally pure quality. Many of the citizens of the district engage in business in Pittsburg, where, until a few months ago, the water-supply was highly contaminated with sewage. Probably a great deal of the typhoid fever could have been traced to infection from this source.

The Monongahela Water Co. supplied the borough of McKees Rocks exclusively until a few years ago. Its supply comes from wells driven in the bottom of a pump pit on the bank of the Ohio River in Esplen. The water is lifted into a receiving well, the bottom of which is level with the river bottom. Through the walls there are cracks which admit the contaminated river water. Therefore, it is not surprising that the typhoid fever rate in McKees Rocks borough should be high. As no records have been kept of typhoid fever in McKees Rocks borough, it is not known whether the rate has been reduced by the entrance into the field of the Ohio Valley Water Co.

The analyses of the Ohio Valley Water Co.'s supply have been made at long intervals, perhaps one a year; so that they prove little as to the average quality. Located as the piping system is in the river, there is always a chance of some break in a pipe, due to rust or loosening up of some joint, whereby an inflow of the water from the river would occur.

During the first part of this year there had been a rise in the Ohio River and on Jan. 6 the Government authorities decided that the rise of the river was sufficient to justify their lowering the series of collapsible dams and allowing a large fleet of coal barges to proceed down the river. After the lowering of these dams the run-off into the Allegheny and Monongahela rivers was suddenly checked by a cold snap and the river began to fall. The water company's wells had up until this time been supplying sufficient water for the system, but as soon as the river stage dropped below the 9-ft. normal stage carried by the dams, the supply began to diminish, due to the reduction of the static head on the well system.

On Jan. 14, the large reservoir in Stowe Township was practically empty and it was deemed necessary by the company to obtain an auxiliary supply at once, since McKees Rocks borough was without fire protection, except by direct pumping. Therefore, a 6-in. connection was made to the river from the 6-in. well at the extreme eastern end of the inner line of wells. River water was admitted through this connection at 10.30 p. m., Jan. 14, and was pumped into the system diluted partly with the water from the rest of the wells until seven in the morning of Jan. 16. The water furnished through this connection was fairly clear until the night of Jan. 15, when the river suddenly began to rise. During the night of the 15th, much mud and other filth was mixed in the water and was noted by the consumers on the following day.

On Jan. 16, the river connection was closed off as the river had risen sufficiently to increase the supply and during the day time the water was pumped from the outer system of wells into the northern district. It was impossible to close off the river connection from the inner system of wells without a diver and he was not obtained until Jan. 17 During the night of the 16th, from 9 p. m. to 7 a. m., the inner system, including the river connection, was again turned on and this supply was pumped into the southern water district.

As a result of the introduction of this raw river water into the system, an epidemic of gastro-enteritis started on the 15th and extended with full sway through the 18th, with some cases as far on as Jan. 25. The progress of the epidemic is shown in the following table:

January.	Cases.
14th	4
15th	354
16th	1,273
17th	983
18th	641
19th	275
20th	98
21st	45
22d	12
23d	11
24th	4
25th	6
Total..	3,706

The main force of the epidemic was felt in the northern water district, in the boroughs on the river front. In these boroughs, which have a total population of 18,000 people, there were 2,887 cases, which represent 16% of the entire population. Westview and Ross Township escaped the infection. This was probably due to the fact that the Bellevue reservoir was fairly well filled before river water was introduced into the mains, and that the water pumped into the Westview system was practically all supplied by the stored water in the Bellevue reservoir.

In the southern district 7% only of the population supplied was affected, due possibly to the fact that the consumers may have become more or less accustomed to sewage poison.

Sixty-three people came down with typhoid fever within three weeks after the supplying of raw river water to the district. A large number of them were unable to overcome the attack of gastro-enteritis. It continued until the case was pronounced typhoid fever by the physician. Sixty of these cases occurred in the north district. Twenty-nine cases were recorded between Jan. 16 and Feb. 1, and 34 cases in February up to the 15th of the month. The cases were distributed as follows:

	Cases.
Bellevue	27
Avalon	18
Ben Avon	11
Emsworth	4
McKees Rocks	3

The purpose of reciting this story at length at t[his] time is to impart a lesson that should not be forgott[en]. Thus the baneful effect of Pittsburg's sewage on t[he] health of the brightest citizens at her doors and t[he] great mass of evidence everywhere admonishes city a[nd] state authorities alike of the futility of defying natur[al] sanitary laws. Once it was impracticable to pur[ify] sewage; now the progress of the art has reached a d[e]velopment where it is possible to remove and destr[oy] the harmful waste products and discharges of hum[an] beings or animals at a reasonable cost.

Change in Sewage Disposal Methods Necessary.

It has been made apparent in the foregoing statement of facts about the existing sewers that the sewerage syste[m] of the city must be changed and improved. It has al[so] been shown why a comprehensive plan of each ind[e]pendent drainage basin system should be made at on[ce] to provide for present needs and in contemplation o[f] future needs when the basin shall have been thoroughl[y] developed. Furthermore, it has been made apparen[t] that the plans for changing the sewers in the district reached by floods must be considered in relation to th[e] flood control problem and the sewage disposal problem. Probably it will not be found practicable in these dis[-]tricts to remove storm water and sewage in one and the same structure.

If it be determined at the outset to separate the sewage from surface drainage, then the preparation of the sewer plans for the lower-lying districts, as well as for the higher districts of the city, may be accomplished without delay.

But the problems of flood control and drainage, and of sewage disposal, are not so local. They must contemplate more area than is now incorporated in Pittsburg's municipal territory. This suggests a metropolitan scheme for the collection and disposal of sewage. At any rate the dictates of sound sense point towards this field of investigation. Provided the preliminary studies, that should be made at once and preferably by the city to expedite progress, prove the proposition to be a feasible and economical one, the time is opportune for the projection of one great main sewerage district. Ordinarily it is cheaper to purify sewage at one or more favorable points where attention may be concentrated on the operation, than to attempt treatment at many independent plants.

The State Department of Health is of the opinion that it will be found economical to largely separate the storm water drainage from the sewage of local basins and main sewers and collect the flow therefrom at one point or a few main points where treatment of the sewage can be best applied and effected, keeping in mind the use of the Ohio River waters below Pittsburg and the ability of this river to receive without creating a nuisance an effluent free from disease germs.

Should the city of Pittsburg desire the assistance of the State Department of Health in bringing about cooperation between said city and the adjacent municipalities named hereinbefore and of others in the Greater Pittsburg district to which sewerage decrees have been issued or are about to be issued, and will request such assistance, it will be gladly given.

Conclusions

As showing the form of the conditional permit or order we quote as follows:

In view of the foregoing circumstances, it has been unanimously agreed by the Governor, Attorney-General and Commissioner of Health that the interests of public health will be subserved by granting a permit, and I do hereby and herein grant a permit to the city of Pittsburg to extend its sewerage system in the Allegheny, Monongahela and Ohio River drainage basins, subject to the following conditions and stipulations: First, That on or before Dec. 1, 1911, the city shall prepare a comprehensive sewerage plan for the collection and disposal of all of the sewage of the municipality and submit the same to the Commissioner of Health for approval.

Second, On or before Dec. 1, 1911, the city shall have concluded such studies and tests as it may deem expedient to inaugurate and shall have decided upon a method for the treatment of its sewage and shall submit a report and plans thereoff to the Commissioner of Health for approval.

Third, Provided that progress has been made with the sewerage and sewage disposal plans and with the determination of the kind of treatment to be installed, and it shall appear that the time herein specified on or before which the plans therefor shall be submitted for approval is insufficient for such purposes, then the Governor, Attorney-General and the Commissioner of Health may extend the time.

Fourth, Meantime, such sewers as it is absolutely necessary to build shall be constructed in conformity with the said comprehensive plans for sewerage in so far as it may be practicable to do so and the plans of these sewers shall be filed in the office of the State Department of Health at the close of the season's work.

The careful attention of the local authorities is called to the facts stated throughout this public document and

the suggestions contained therein. The State Department of Health will be glad to act in an advisory capacity to further the policy of bringing about the ultimate discontinuance of the discharge of untreated sewage into the waters of the state in the city of Pittsburg or its vicinity.

This permit before being operative shall be recorded in the office of the Recorder of Deeds for Allegheny County.

.....
Commissioner of Health.

Harrisburg, Pa., Jan. 15, 1910.

BY AGREEMENT OF THE GOVERNOR, ATTORNEY-GENERAL AND COMMISSIONER OF HEALTH.

The Nine Mile Run District.

This district is described in the report as follows:

Nine Mile Run Valley is at the eastern boundary of that portion of the city lying between the Allegheny and Monongahela rivers which drains to the latter and it includes territory beyond the city.

Nine Mile Run enters the Monongahela River at Brown's Bridge in the southeastern part of Pittsburg about one mile west of the eastern city line. It has numerous branches draining a total area of about 4,300 acres of which about 2,000 acres lie within the limits of Pittsburg, while the remaining area includes Wilkinsburg, Edgewood and a portion of Swissvale boroughs, and portions of Penn, Wilkins and Braddock Townships. Two of its three principal branches rise in Penn and Wilkins townships, flow in a general southwesterly direction into and through the old Thirty-seventh and Forty-first Wards of Pittsburg and the borough of Wilkinsburg. Here they unite to form the run which flows consecutively through Edgewood and Swissvale. On again entering the city of Pittsburg, it is joined by another considerable branch from a valley to the north known as Fern Hollow lying within the city limits. The Run is about five miles long and has a fall of about 600 ft.

The topography of the basin is very much broken, its numerous branches draining many small ravines, most of them quite narrow and deep. The lower portion of the valley has generally abrupt slopes from 150 to 300 ft. in height, between which lies a practically level strip of bottom land a mile or more in length and about 1,000 ft. wide, with Nine Mile Run generally following its eastern border.

All of Pittsburg sewers in Nine Mile Run Valley are on the combined principle, that is, they take both sewage and storm water, and all empty into Nine Mile Run except the Kelley Street sewer draining the old Thirty-seventh Ward, which connects with a drain which slopes in the opposite direction and finally empties into the Allegheny River.

The population of this district is now placed at about 35,000, of which only 10,000 is in Pittsburg. The prospective population of 155,000 is divided as follows: Pittsburg, 59,500; Wilkinsburg, 47,500; Edgewood, 11,500; Swissvale, 12,500; various townships, 24,700.

The order states that the discharge of sewage into Nine Mile River must be stopped, and that untreated sewage cannot be discharged into the stream indefinitely. Joint action for sewerage and sewage treatment is urged, under a comprehensive plan, and the city is ordered to make the necessary studies to that end, either alone or in conjunction with the other municipalities. It is assumed that the purification works will deal with little but sewage proper, to which end some reconstruction work for separating storm water will be necessary. Copies of the order have been or will be furnished to the Boroughs of Wilkinsburg, Edgewood, and Swissvale, and to the townships of Penn, Wilkins and Braddock.

Saw Mill Run District

Saw Mill Run drains an area of 20 sq. mi., of which 75% is outside the city limits of Pittsburg. The stream rises in Bethel Township, eight miles south of the Monongahela River, and flows in a generally northerly direction through Baldwin Township and by Carrick Borough, through or alongside portions of the city, first a part of Lower St. Clair Township and then through the city again. Carrick Borough has been given a permit to discharge sewage into Saw Mill River, provided that by July 1, 1910,

either alone or in conjunction with Mt. Oliver and Knoxville and the city of Pittsburg [it] shall prepare a plan for some other disposal . . . and submit the same to the [State] Commissioner of Health for approval.

Mt. Oliver Borough has been given a similar permit, and Knoxville has been notified of the requirement thus laid down.

It seems probable, the order states, that Pittsburg will plan a trunk sewer extending down the valley of Saw Mill Run, and it is recommended that this be made large enough to carry the sewage of the entire drainage district, but little, if any, of the surface drainage. The order is, therefore, so worded as to require the filing of plans for an improved sewerage system by Dec. 1, 1911, and also plans for sewage treatment by the same date, with the proviso that more time may be granted for the latter, if necessary, and if a proper effort has been made to comply with the order.

Power Cultivation of the Soil.*

By E. W. HAMILTON.†

It would be difficult to say who it was that first conceived the idea of mechanical power in connection with the cultivation of the soil. It is recorded as far back as 1618, that David Ramsey and Thomas Wildrose patented an invention for plowing without horses or oxen. These men, it appears, were unable to persuade their countrymen of the feasibility of their plans and were compelled to abandon their schemes and their inventions, leaving no records of the modes of working them. Richard L. Edgeworth, an Irishman, about the year 1730 produced an engine carrying an "endless road" with it. All methods, however, up to 1832 appear to have proved abortive, but during this year Mr. John Heathcote, a lace manufacturer in Devonshire and a Member of Parliament, brought out and patented his celebrated plan for draining and cultivating the land by an entirely new set of machines. Mr. Heathcote brought out his engine on the first of April, 1834. It appears that he intended to especially cultivate and reclaim bog land. A plow was constructed by a Mr. Parker, who was at that time consulting engineer to the Royal Agricultural Society of England, which, on being tried, performed admirably, this being the first time known when a mechanical power was used to plow land. It was said by many who saw this machinery at work that if these men had adapted their invention to plowing on ordinary land instead of to the reclamation of bog land, they would have succeeded. As it was, however, after spending some $60,000 they abandoned their scheme. The machinery consisted of an engine traveling along the headland on one side of the field and an anchor on the other. When working on bog land an "endless web" for forming a road was used. The cultivating implements were drawn backwards and forwards between the engine and the anchor.

In 1849 Messrs. Barrett and Exall, of Reading, England, constructed what may be considered the first apparatus for working plows and cultivators by the ordinary portable engine, this being the first attempt to plow land with a stationary engine. This was the original "roundabout system," as it is now called, in which ropes 1,600 yards long were used. This machinery was actually set to work but, after plowing some 60 acres at the rate of about five acres a day, the rope broke and many other difficulties cropped up, causing the inventors to abandon their project.

Next to the "Roundabout" method came the "Double engine" method. A set of this machinery was exhibited at the great English Agricultural Exhibition of 1851 by a certain Lord Willoughby D'Ersby. It consisted of engines with winding drums working upon opposite headlands, traveling, as work proceeded, upon a tramway of planks. The plows were drawn from engine to engine by means of a chain which seems to have been the cause of the want of success. It was claimed that this machinery was capable of plowing four acres per day to a depth of 9 ins.

By this time traction cultivation had taken a practical form and many firms were expending large sums of money experimenting and struggling for supremacy. Although there were now a number of different methods and appliances of cultivating land by mechanical power, these were more or less carried out upon one of the five following plans: (1) engines traveling over the land and drawing the cultivating implements after them; (2) locomotive engines working on railways and drawing implements behind them; (3) stationary engines drawing the implements by means of wire ropes; (4) engines moving along the headlands and drawing the implements by means of wire ropes; (5) engines placed in punts floating on canals and drawing implements by means of wire ropes.

Method One is now in general use on the North and South American continents. This method was formerly in use in England where traction cultivation may be said to have had its origin, but owing to the climate and the small fields, it was abandoned. Various classes of implements were designed for working behind the traction engine, such as plows drawn by chains of different lengths, Romaine's rotary cultivator and the Darby land digger. This Darby land digger was one of the most peculiar freaks in traction cultivation that has, perhaps, ever been designed. There was a large triangular frame constructed and on this frame were a number of feet. These feet were not unlike the ordinary disk of a disk harrow with the concave side turned down. These disks were made to revolve on an angle at about 400 r.p.m. Machines were put out and one of them was at work in 1904 in Regina, Canada, and about all that can be said of it is that it tore up the ground and threw it in all directions.

Many schemes were brought out to enable the engines to travel on soft ground, the most noteworthy of which was the Boydell scheme.

This consisted of an "endless web" or "endless railway" which was attached to the wheels of an engine in such a manner that each section fell under the wheels as the several parts approached the ground. Owing, however, to the large number of joints into which the dust and dirt was constantly working, the wear and tear became so great that the scheme was abandoned. Something of a modification of this is the Holt Caterpillar engine.* This engine, however, makes a sort of tread track and is claimed to be very effective as regards its tractive power in soft ground.

Method Two, in which it was proposed to use locomotives working on railways, was what is known as the Guidsway method of cultivation and was first invented by an English navy officer by the name of Halket. This method was never, except upon quite a small scale, tested practically. Halket proposed to lay down rails in the ordinary way except at a distance of 50 ft. from rail to rail. The rails were to be laid upon a foundation of brick work 21 ins. in width and 2 ft. in depth. At each headland, rails were laid at right angles with the others and low enough to receive the working machine or platform in order to remove it to fresh ground, when it arrives at the headland. These cross rails were to be placed at a distance that would allow of a trolley sufficiently wide to carry the working machine, possibly 15 to 20 ft. apart. The rails were to be continued at one headland out of the field to convey the apparatus thither when the field was finished. The rails were also to be continued from field to field in order to facilitate the removal of the machine when required to work on fresh fields. The rails were, of course, to be permanent, being fixed to ties inserted in the brick work, the two upper courses of which were to be set in cement. The land was to be laid out in square fields.

The working machinery consisted of a platform to which was attached the plows that contained from 6 to 12 bottoms. On each end of the platform was to be stationed a steam engine of 5 or more horse-power connected together by a shaft and a set of gearing which engaged with the 16 wheels, 8 on each side. One set of plows was to work in one direction and one in the other.

Method Three, which is known as the "roundabout" worked as follows: The engine was placed on the headland in one corner of the field and was connected by a shaft to a windlass. This windlass consisted of a frame on four wheels upon which were mounted horizontal drums and on these were coiled and uncoiled the ropes. One rope led off direct to the anchor on the headland and from thence to the plow. The other rope ran over a sort of capstain round a snatch block to the anchor on the other headland and then to the plow. The anchors moved alternately, being fitted with gears by means of which, when the plow approached them, they wound themselves forward on the ropes. The drums on the windless were alternately thrown out of gear, thus causing the plow to move to and from upon the field.

Method Four may be divided into two classes, (1) one in which only one engine is used in connection with a self-moving anchor, and (2) one in which two engines are employed, drawing the cultivating implement to and fro by means of a steel cable. In the single-engine class, the engine was fitted with two winding drums and worked along one side of the field while at the other was fixed a self-moving anchor. At the corner of the field and on the same headland as the self-moving anchor, a snatch block was fixed. The cable from one drum of the engine was carried around this snatch block to the anchor and thence to the plow while the other cable ran direct to the implement. The two drums were thrown alternately in and out of gear by one lever; thus giving a to-and-fro movement to the implement.

If a careful record were made of all of the plowing outfits at use in the world to-day, I believe it would reveal the fact that the double-engine method is the one in most general use. A number of these outfits have been used in the United States, mostly in California. Two or three outfits have been sold in Canada. With the "double-engine" class two self-moving plow engines work on opposite headlands, each alternately pulling the plow or other implement toward itself, the engine not at work, paying out its rope while moving forward into position for the return journey.

This method has made a hard fight for popularity, but despite any statements to the contrary, even the English manufacturers who build practically all of these engines, are rapidly turning toward the direct method. One great disadvantage is the cost, as a complete set of engines and tackle cost about £5,000, or $25,000.

Perhaps the most novel method of traction cultivation that has been tried is that which was used for a considerable time on the plantations of Demerara, British

*Brief abstract of a paper presented at the third annual meeting of the American Society of Agricultural Engineers, Ames, Iowa, Dec. 28, 1909.

†Editor, "Canadian Thresherman and Farmer," Winnipeg, Manitoba.

*Described in Engineering News, Feb. 18, 1909.—Ed.

Guiana. Much of the land under cultivation in Demarara has been reclaimed from the tides and the surface of the fields is 4 or 5 ft. below the level of the ordinary high-water mark. Navigation and drainage canals were laid out and the fields were divided into tracts. There being practically no roads on the estates, all of the products were transported in punts. Fields which were 400 yds. long, by about 150 yds. wide, were laid out with open drains. This caused an enormous waste of land, but this waste was more than made up by the gain in labor. Land was cheap in Demerara, but labor was expensive, and the open drains were held responsible for this costly method of soil cultivation. A fall of 6 ins. of rain in 24 hours was not unknown in Demerara, the average rainfall being about 100 ins. per annum.

In place of having engines on the headlands, they were fixed in boats which floated in the canal. The implements were pulled to and fro just as with land engines. To move the boats ahead at each round of the implement, a steel cable which was attached to an anchor near the end, was wound onto a horizontal drum thereby pulling the boat forward the desired distance at each turn of the implement.

These methods, with the exception of the direct method, are now practically ancient history. They were born of necessity, and while each and every one of them was short-lived and of very little practical value, they nevertheless served to keep alive the idea of power cultivation.

The use of the direct method of traction cultivation began to come into wider use in the United States and Canada about six years ago. Up to that time there had been a number of outfits at work, consisting of an ordinary threshing engine and such plows as the farmer might have at hand. He found the outfit very unsatisfactory for two reasons: First, his engine was not designed for tractive efficiency, and secondly, was not durable. The gears were small and made of cast iron. The result was that they were out quickly and the owner had an enormous repair bill through their breakage. It was necessary that he take a two or three-bottom horse plow and with one or two or three more of its kind and a crude arrangement of chains, ropes and cables, make up suitable hitches. This caused him a great deal of trouble and annoyance and the work done was not always satisfactory.

The builders of traction engines saw that there was something to this traction-cultivation proposition and they began to redesign their engines, putting broader rims on the wheels, strengthening the gears and increasing the horse power.

The plow manufacturers also helped. They saw that there was something to traction cultivation and the multiple-bottom gang plow was put on the market. These gangs served the purpose fairly well, but they were too stiff and rigid. They did not provide for the necessary flexibility that is one of the requisites of the traction plow. The required flexibility has been secured by making each plow independent of all the others, each being raised or lowered by its own levers. Most of the plow makers are putting out steam plows, some good and some bad, but all, in the main, serving their purpose fairly well.

This engine-gang business marks the beginning of an era wherein the manufacturer of tillage instruments is making an effort to furnish the farmers with tools that he can attach to his engine just as easily as he could attach the old style of implement to a team of horses. Drills, disk harrows, drag harrows, soil packers, cultivators, etc., etc., that are designed to pull with horses are being used with more or less success in tractioning the soil. Thus far, there has not arisen among the farmers a demand for a specially designed machine. The old implements are serving the purpose fairly well, and until some ingenious individual demonstrates that there is something better the implements as they are now manufactured will hold the field.

There is, however, one thing that is badly needed in connection with tractioning the soil and that is a suitable hitch for every kind of implement. The plow builders have overcome the difficulty of building their plows so that they can be readily hitched to the engine without any makeshift on the part of the farmer. But when it comes to attaching drills and harrows and cultivators, the farmer is up against a serious difficulty. He has to use his own ingenuity and such things as he may have at hand, which in most cases are not very satisfactory. It seems to me that there is a big field here for any manufacturer who will work out and build suitable hitches that will apply to the various implements that are now being pulled behind the traction engines. These hitches might be made adjustable, so that one hitch with a few slight adjustments could be made to accommodate any class of implement.

Every year we see more and more of this combination work and especially so since the advent of the gasoline tractor. There is no getting away from the fact that this has done more to further traction cultivation than anything else.

Hundreds of letters come into the office of the "Canadian Thresherman and Farmer" every year that contain the one question: "Do you think the gas tractor more suitable for my purpose than the steam engine?" And I have but one answer to give them; that is, that "I do not know."

Until about three years ago the gasoline traction engine was in an experimental stage. It had never demonstrated what it could do for any great length of time. It did not have an opportunity to stand up against its steam brother for a number of years. Any comparison that could be made was largely a matter of theory, and theory and practice in tractor work do not stand on the same ground. The indications are, however, that the gas tractor as a farm power is going to take the place of steam, when I say farm power, I mean a power that can be used in practically every farm operation. Test after test has proven beyond a doubt that it is economical. That it is handy and easy to manipulate goes without saying and that ample power can be developed for the needs of the average farmer is also a settled fact.

There is one thing that is greatly in its favor when it comes to working the soil and that is its weight. In proportion to the power developed, the average is by no means as heavy as the steam engine of the same size and capacity. Traction cultivation must be done under all sorts of conditions of weather and soil, and this being true, the great weight of the steam tractor is sometimes a serious handicap. The ideal engine, it seems to me, in traction cultivation, is one that has a maximum capacity with a minimum of weight, but when it comes to actual work and the engine is put to the severe test of plowing, there must be sufficient metal in the machine so that it will be durable. A great many of the gas tractors that have been built have failed in this particular. They have worked for a short time but have shown an enormous repair bill. The comparative costs of working the soil with steam or gasoline are open to discussion. A record of cost that would hold true in one locality would be entirely wrong in another. Given plenty of water and good, cheap coal, steam will make a beautiful record. On the other hand, given a locality where coal must be brought from a long distance and where water is scarce, the use of steam power on a farm proves a distinct failure. In the province of Alberta, Canada, during the past season, dozens of steam outfits were tied up, not being able to turn a wheel on account of the scarcity of water and, during the early part of 1909, many more were seriously tied up on account of the coal strike that occurred in the Crow's Nest Pass coal mines.

That which is true in one locality regarding the gasoline tractor is practically true in another, the only difference being in the price of fuel. It is also true that the use of the gasoline traction engine at the present time is somewhat of a fad, the farmer, in very few cases, having any definite knowledge of its real practicability. The farm papers have opened their columns wide to the discussion of this form of mechanical power and the manufacturers of machines now upon the market have heralded far and wide the advantages to be gained from cultivating the soil with a gas traction engine. I am of the opinion and I state it frankly that these same manufacturers know very little about the real proposition of tractioning the soil with a gas tractor. It is true that they have put their machines through some pretty severe tests, but when it comes to real, practical, every-day work, year in and year out, as compared with the steam engine, I doubt if very many of them could give any real comparative statement that would be an authority.

The purchaser of a gasoline engine to-day is left very largely to himself, in so far as his field of operation is concerned. There is very little experience back of the thing to which he can turn and his success or failure is his own. To me it seems that there is a crying need for education along this line. Time is too short and our agricultural products are becoming too valuable to permit the farmer to stumble blindly into such a vital proposition as tractioning the soil. It seems to me that there is a crying need on the part of the farmers for the manufacturer of gas traction engines to work experimental farms of his own. It would enable the manufacturer to secure an accurate record of costs, so that he could go to the prospective purchaser of a gas traction engine for soil cultivation purposes with data that would be based upon actual work done and not upon data secured from the testing floor.

The records as they are procured from the farmers at the present time as they have carried on traction cultivation, amount to very little. During the past three or four years, I have gone over hundreds of these records from people who have done traction plowing in Canada and there is such a gross amount of inconsistency in the reports that they are really nothing but a farce.

The average traction engine owner does not know how to get at costs. He does not know what to include. The cost varies all the way from 75 cts. up to $5 per acre, conditions being practically the same. Three fairly representative reports are appended. Two are for internal-combustion motors and one for a steam engine.

The man who farmed forty years ago used only the crudest implements. He tickled the earth, so to speak, with a hoe. To-day it is different. The man who operates a farm should be much of a skilled mechanic. He operates complex machinery that requires accurate and careful adjustment, in order that it may do its work properly.

The gasoline traction engine is going to bring about this need of skilled labor more than any other one thing. The hired man of the future must be able to use his head as well as his hands. He will be required to run a traction engine and all of the machinery driven by it. Not only will he be required to run it, but he will be required to do it economically. Skilled labor always has a common bond of relationship. At the present time there is no such thing as the Hired Man's Union. There is no walking delegate that goes from farm to farm and dictates to the employer how many hours he shall work his men or how much per hour he shall pay them. But skilled labor will band itself together into a union that will control, in a measure, the farm-labor question. There will be a regulation of hours, but there will also be a regulation of wages, and when the time comes, the farm and the manufacturing establishment will be placed upon the same basis, in so far as the cost of production is concerned.

The farmer of the future will get down to a system of costs where every gallon of gasoline or kerosene used must represent so much work, the same as it does in our large manufacturing establishments of to-day.

COMPARATIVE PERFORMANCE OF TRACTION PLOWS.

Outfit No. 1:	
One barrel kerosene, 42 gals., at 26 cts.	$11.0
Lubricating oil and gasoline for starting	1.0
Labor (engineer and steersman)	6.0
Board for above	1.0
Repairs	2.0
Depreciation (life estimated at eight 60-day years)	6.5
Interest on cost, $3,400, at 7% per annum, divided into 60 working days	4.0
Total daily expense	$31.5
Average day's work, acres	22.5
Cost per acre, traction plowing	$1.4
Outfit No. 2:	
40 gals. coal oil	$10.5
2 gals. gasoline	.6
Other oils	.5
Interest and wear on engine	2.0
Engineer	4.0
Plowman	2.0
Total daily expense	$19.4
Cost of summer fallowing, per acre	$1.3
Outfit No. 3 (Steam):	
2 tons of Galt coal	$9.5
Engineer	3.5
Steersman	2.5
Man and team to haul water	4.5
Man and team to haul coal	4.5
Cook	1.1
Wear on engine and plows	5.0
Interest on investment	1.2
Oil and sundries	1.5
Board for five men at 75 cts. per day	3.7
Total daily expense	$36.9
Average day's work, acres	42.2
Cost per acre	87.3 cts.

Notes from Engineering Schools.

YALE UNIVERSITY.—The Director of the Sheffield Scientific School, Dr. Russell H. Chittenden, has announced a gift to the school of $250,000, for the construction and equipment of a new mechanical-engineering laboratory. Two graduates of the Sheffield School, of the class of 1888, Mr. George G. Mason, of New York City, and his brother, Mr. William S. Mason, of Evanston, Ill., have given this money to the Board of Trustees, who will provide a site for the building.

The new laboratory will be located on Hillhouse Ave., nearly opposite the Leet Oliver Memorial building. It will have a frontage of about 85 ft. on Hillhouse Ave., extending back 200 ft., with a rear entrance on Temple St. It will be four stories in height and will be constructed of Indiana limestone and brick. There will be approximately 50,000 sq. ft. of floor area and 880,000 cu. ft. volume of rooms. The entire equipment will be new and will consist of the most modern appliances for assisting the student in studying those fundamental principles of applied science which are closely related to mechanical engineering—such as relate to the strength of materials, to the combustion of fuel in furnaces and in internal combustion engines, the steaming of boilers of different types, the use of saturated and superheated steam, the artificial production of cold, to the compression of air, to hydraulics, power transmission, heating and ventilation, etc. Besides furnishing a

modern laboratory for under-graduate instruction, it is expected that when the building is suitably equipped, it will encourage graduates of the school to remain for four years of post-graduate work. With the opportunities available, research work in engineering science may be carried on by research fellows and members of the teaching staff.

It is expected that the plans will be ready so that work on the laboratory may be begun by next July and the building completed and equipped by June, 1911.

A MOTOR CAR WAS WRECKED BY A BLAST Feb. 6 on the private railway from Kelvin, Ariz., to the Ray copper mines and its seven occupants were killed. Reports state that the man who had lighted the fuse, the foreman of a gang of laborers at work in a cut, warned the motorman in time to have prevented the accident. The motorman, however, went ahead at full speed, apparently in the belief that he could get safely past the blast before it exploded. The names of the six passengers in the car, all of whom were killed, are given in newspaper reports as follows: J. B. Joyce, A. S. Bieber and J. C. Griffin, civil engineers employed by the Ray Consolidated Copper Co., and R. P. Coleman, Water C. Franz and W. H. Freeland mining engineers of Salt Lake City, Utah. Mr. Frenz and Mr. Freeland were in the employ of Mr. Henry Krumb, M. Am. Inst. M. E., of Salt Lake City.

TWO MORE COAL MINE EXPLOSIONS followed closely on the heels of the two noted in our last week's issue.

An explosion, Feb. 2, in the Palau mine of the Esperanzas Mining Co., at Los Esperanzas, Mexico, killed 70 miners and severely injured about 20 others. The accident is ascribed to the ignition of gas by a miner's cigarette, smoked in violation of the company's rules.

An explosion at the Ernest mine, five miles north of Indiana, Pa., Feb. 5, resulted in the death of eleven men. One man, at work near the place where the explosion originated, is reported to have saved himself from suffocation by crawling a quarter of a mile. Most of the victims appeared to have been killed by suffocation.

In the Drakesboro, Ky., explosion, Feb. 1, later reports give the number of men killed as 34 and in the explosion at Primero, Colo., Jan. 31, the number killed is now given as 75. This gives a total of 190 lives lost in the four explosions within one week.

RAILWAY ACCIDENT BULLETIN No. 33 of the Interstate Commerce Commission gives the total number of collisions and derailments in the United States during the months of July, August and September, 1909, as 2,751—1,288 collisions and 1,463 derailments. The total number of persons killed in train accidents was 193 and 3,752 others were injured. Including railway accidents of all sorts 852 persons were killed and 19,241 injured. The increase in the total number killed, all causes, was 264 over the preceding quarter and 118 over the corresponding quarter of the year 1908.

The total number of passengers killed, not including postal clerks, express messengers and others carried under special arrangements, was 87. Of these, 42 were killed in train accidents and 30 were killed by falling from cars or while getting on or off. Of the train accidents 229 collisions and 192 derailments affected passenger trains. The total number of derailments due to defects of roadway was 268 while those due to defects of equipment numbered 671. The bulletin states that the only favorable indication afforded by the statistics it presents is the fact that "the total of employees killed in train accidents and in coupling cars do not show such decided increases as do those of employees killed from other causes."

TYPHOID FEVER AT RICHMOND, VA., caused 28 deaths in 1909. This gives a death rate of 25.6 per 100,000, which is 42% lower than that of any previous year on record. The reduction is believed to be chiefly due to health-protective work in other lines than those relating to the public water-supply.

THE NEW PENNSYLVANIA R. R. TERMINAL at 31st St. and Seventh Ave., New York City, will be opened for Long Island R. R. suburban traffic on April 1. The other passenger trains westward under the North River, however, will not begin running until June 1 or later. The first 24 electric locomotives which are to handle the traffic in this terminal are being completed at the Altoona shops.

THE RIVER AND HARBOR APPROPRIATION BILL, according to press reports, is being drafted to provide appropriations of about $35,000,000, and will involve the beginning of work on waterway improvements estimated to attain a final expenditure, in the course of a dozen years, of some $600,000,000. This latter estimate includes $80,000,000 for the Mississippi River and $63,000,000 for the Ohio River.

THE TWO MAMMOTH STEAMSHIPS which the White Star Line is building and which are expected to be ready for the summer of 1911 are to be rivaled in size by two large vessels which the Hamburg-American Line is to have built, according to a cable dispatch in the New York "World" of Feb. 7. The Hamburg-American vessels are to be 850 ft. long, 92 ft. beam, 66 ft. in depth with about 34 ft. draft. Reciprocating engines are proposed, to develop about 48,000 HP. and give a speed of 21 knots. The vessels will accommodate 4,800 passengers and carry a crew of 750. The White Star liners, the "Titanic" and "Olympic," as noted in Engineering News, Feb. 11, 1909, are to be 900 ft. long, with 90 ft. beam. Their expected speed is only 20 knots.

THE UNPRECEDENTEDLY HEAVY RAINFALL in parts of Utah has brought trouble to another railway. The destruction of a large part of the line of the San Pedro road, running from Salt Lake to Los Angeles, was noted recently. It now appears that the extraordinary inflow into Great Salt Lake has raised its level to a higher point than has ever been recorded since the country was settled. The Lucin cut-off, built across the lake by the Southern Pacific Ry. a few years ago, is threatened by the rising waters, and if the rise continues it may be necessary to temporarily abandon the line and raise the height of the track. When this cut-off was constructed, the track was about 20 ft. above the lake level.

THE FIRST TUNNEL driven in the United States on a transportation line is said to be the Canal Tunnel at Lebanon, Pa., on the old Pennsylvania canal, which extended from Middletown, on the Susquehanna River, to Reading, on the Schuylkill River, a distance of 79 miles. It is stated that the city of Lebanon will next year hold a celebration in honor of the centenary of the beginning of work on this old tunnel. The origin of the canal enterprise dates back to 1762, and the projectors were David Rittenhouse, the astronomer, and Dr. William Smith, Provost of the University of Pennsylvania. These noted scientists, however, were far in advance of their time, and not until after the close of the Revolution, in 1794, was a company organized to construct the proposed canal. Actual work on construction began in 1811, but the canal was not completed until 1837. The tunnel at Lebanon is driven through solid rock and is about an eighth of a mile long. The main part of the canal was long ago abandoned and filled, but about a mile in length at Lebanon, including the old tunnel, is still open.

Personals.

Mr. P. H. Norcross, Assoc. M. Am. Soc. C. E., of the Solomon-Norcross Co., Atlanta, Ga., has been appointed Consulting Engineer for the Georgia State Board of Health.

Mr. W. W. Whitenton has been appointed Vice-President and General Manager of the Chicago, Rock Island & Gulf Ry. to succeed Mr. J. W. Robins, recently elected President of the Trinity & Brazos Valley Ry.

Mr. J. F. Sheahan, Master Mechanic of the Southern Ry. at Knoxville, Tenn., has resigned to take a similar position with the International & Great Northern R. R. at Palestine, Tex.

Mr. Walter M. McFarland, M. Am. Soc. M. E., Acting Vice-President of the Westinghouse Electric & Manufacturing Co., East Pittsburg, Pa., has resigned to engage in other business.

Mr. Hallet R. Robbins, M. Am. Inst. M. E., who has been in Boston for several weeks, has returned to the West and taken over the management of the Ironsides gold mine near Boise, Idaho.

Mr. Sam. R. Murray, Superintendent of the municipal asphalt repair plant of Indianapolis, Ind., from June, 1908, to Jan. 1, 1910, has gone to Denver, Colo., to take charge of the asphalt department of the bureau of highways.

Mr. D. W. Cooke has become President of the Metropolitan Street Ry. Co., Kansas City, Mo., succeeding Mr. Bernard Corrigan. Mr. Cooke was formerly General Traffic Manager of the Erie R. R., with headquarters at New York City.

Mr. Alten S. Miller, Assoc. Am. Inst. E. E., formerly General Manager of the Consolidated Gas, Electric Light & Power Co., of Baltimore, Md., has been made President and General Manager of the Union Electric Light & Power Co., of St. Louis, Mo.

Mr. E. G. Buckland, Vice-President of the New York, New Haven & Hartford R. R., at Providence, R. I., has been made Assistant to the President to succeed Mr. H. A. Fabian, who will fill the newly created position of manager of purchases and supplies.

Mr. George L. Robinson, Assoc. M. Am. Soc. C. E., President of the New York Sewage Disposal Co., who has been in Europe for several weeks, examining municipal sewage disposal works, sailed from Liverpool for New York City Feb. 5 on the "Baltic."

Mr. J. Currie has been appointed Superintendent Engineer of the Cunard Steamship Co. to succeed George Thompson, who died Dec. 27. Mr. Currie was formerly Chief Engineer of the "Mauretania," and has been in the Cunard company's service for 37 years.

Mr. Darius Miller, First Vice-President of the Chicago, Burlington & Quincy R. R., has been made President to succeed Mr. E. B. Harris, retired. Mr. Miller first entered railway service in 1877 as a stenographer in the general freight office of the Michigan Central R. R.

Mr. P. J. O'Brien, Superintendent of the Madison division of the Chicago & Northwestern Ry., has been transferred to the Galena division to succeed Mr. W. D. Beck, resigned. Mr. G. B. Vilas, Assistant Superintendent of the Madison division, has been promoted to succeed Mr. O'Brien.

Mr. J. E. Buker, Superintendent of the car department of the Illinois Central R. R., at Chicago, Ill., has resigned to become First Vice-President of the Chicago Car Heating Co. His position with the Illinois Central has been abolished and its duties will be assumed by Mr. R. W. Bell, Superintendent of Machinery.

Mr. Howard G. Hetzler has been appointed President of the Chicago & Western Indiana Ry. He was formerly President of the Metropolitan Elevated Ry., of Chicago, and has been Superintendent of Terminals of the Chicago, Burlington & Quincy Ry., and Engineer of Maintenance of Way of the Chicago, Indianapolis & Louisville Ry.

Mr. G. R. Solomon, Assoc. M. Am. Soc. C. E., of the Solomon-Norcross Co., civil, structural and hydraulic engineers, Atlanta, Ga., sailed Feb. 5 from San Francisco for a trip around the world, during which he will spend some time in the investigation of hydro-electric and hydraulic developments in foreign countries. He expects to be away about six months.

Mr. Arthur N. Talbot, M. Am. Soc. C. E., Professor of municipal and sanitary engineering at the University of Illinois, has been awarded the Chanute medal in civil engineering by the Western Society of Engineers for his paper on "Tests of Cast-Iron and Reinforced-Concrete Culvert Pipe." Provision for three medals to be awarded annually by the Western Society of Engineers for work in mechanical, electrical and civil engineering, respectively, was made by Dr. Octave Chanute.

Mr. Howard K. Bell has resigned his position as Chief Engineer and General Manager of the Lexington Hydraulic & Manufacturing Co., Lexington, Ky., and will enter upon general practice as a sanitary and hydraulic engineer. He will continue, however, in charge of the engineering work of the Lexington Hydraulic & Manufacturing Co. Mr. W. S. Cramer, who has been Chief Engineer of the pumping station for a number of years, will succeed Mr. Bell as General Manager.

Mr. Frank T. Fowler, a member of the Board of Local Improvements, of Chicago, has been appointed temporarily as Superintendent of Streets of that city. In the recent civil-service examination, Mr. J. T. Fetherston, Assoc. M. Am. Soc. C. E., of New York City, stood at the head of the list, but an organization of ward superintendents brought suit to contest the legality of his appointment. Under these circumstances Mr. Fetherston declined the appointment. Mr. Fowler is stated to have ranked sixth on the list of those who took the examination.

Mr. A. W. Grosvenor, recently Assistant Engineer in connection with the Grand Central terminal improvements of the New York Central Lines at New York City, has opened an office at 311 Bank Block, Fort Wayne, Ind., for the practice of civil engineering. Mr. Grosvenor is a graduate of the Massachusetts Institute of Technology, class of 1899, and has been employed consecutively as Assistant Engineer of Maintenance of Way on the Pennsylvania Lines West of Pittsburg; Assistant Superintendent of caissons with S. Pearson & Son, Incorporated, on East River tunnel construction at New York City, and Night Superintendent with the United Engineering & Contracting Co., of New York City.

Mr. I. M. De Varona, M. Am. Soc. C. E., Chief Engineer of the Department of Water Supply, Gas and Electricity of the Borough of Manhattan, New York City, has been made Chief Engineer of the reorganized department for the entire city, with jurisdiction in all boroughs. Mr. W. W. Brush, Assoc. M. Am. Soc. C. E., Engineer of Distribution, Board of Water Supply, New York City, has been made Deputy Chief Engineer under Mr. De Varona. Mr. Walter E. Spear, Assoc. M. Am. Soc. C. E., has resigned as Chief Engineer of the Department of Water Supply in the Borough of Brooklyn and that position has been abolished. Mr. Spear has returned to the service of the Board of Water Supply, from which he was transferred to the Brooklyn position in January, 1909.